NASA/TM–2012-215890

Atmospheric Research 2011 Technical Highlights

August 2012

Cover Photo Captions:

Top Left: *Time-lapse photo of Delta II launch track over the South Pacific Ocean on October 28, 2011 at 2:48 AM PST. A star track is also visible near the upper portion of the arc.*

Bottom Left: *A "Blue Marble" image of the Earth taken from the VIIRS instrument aboard the Suomi NPP satellite. This composite image uses a number of swaths of the Earth's surface taken on January 4, 2012.*

Right: *The NPP satellite atop a Delta II rocket attached to the Fixed Umbilical Tower at Vandenberg Air Force Base prior to launch at sunset on October 27, 2011.*

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Atmospheric Research 2011 Technical Highlights

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

August 2012

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Dear Reader:

Welcome to the Atmospheric Research 2011 Technical Highlights report. I thank you for your interest. During the last 17 years, the Laboratory for Atmospheres has published an annual report each year describing organizations, research, missions, models, data analysis, and summaries of our accomplishments. During 2011 the Earth Sciences Division underwent a reorganization wherein the Laboratory for Atmospheres was subdivided into three Laboratories under the newly created Office of Deputy Director for Atmospheres in the Earth Sciences Division. In addition, a new field office was created at the Wallops Flight Facility to support atmospheric field campaigns. Within the new organizations research will continue as before but with more emphasis on coordination and integration among disciplines. In light of the new emphasis, we have decided that the annual reporting should focus on highlights of research activities rather than organizational structures, facilities, and the multiple other topics previously covered in the Laboratory for Atmospheres Annual Report. These areas will be addressed in future annual or semiannual Division reports and strategic plans. This report, as before, is intended for a broad audience. Our readers include colleagues within NASA, scientists outside the Agency, science graduate students, and members of the general public. Inside are descriptions of our science highlights and summaries of our education and outreach accomplishments for calendar year 2011.

The three Laboratory's and the Wallops field office consist of approximately 250 scientists, technologists, and administrative personnel and are part of the Earth Sciences Division in the Sciences and Exploration Directorate of NASA's Goddard Space Flight Center. Under the new Office of Deputy Director, "advancing knowledge and understanding of the Earth's atmosphere" will continue as the overall mission objective of atmospheric research. Satellite mission, field campaigns, peer reviewed publications and successful proposals are essential to our continuing research.

The following are some noteworthy events that took place during 2011. Congratulations to Jim Gleason and his project science team for their efforts in support of the successful launch of the National Polar-orbiting Partnership (NPP) satellite in October. NPP serves as a bridge mission from NASA's Earth Observing System (EOS) of satellites to the next-generation Joint Polar Satellite System (JPSS), a joint program between NASA and the National Oceanic and Atmospheric Administration (NOAA) that will collect weather and climate data. NPP carries five advanced instrument systems that are expected to improve forecast skills out to five to seven days in advance of extreme weather events, including hurricanes, and severe weather outbreaks. The five-year life mission will also extend more than 30 crucial, long-term datasets that include measurements of the atmosphere, land and oceans, including atmospheric ozone. Goddard manages the NPP mission; Jim is the project scientist for NPP and future JPSS Missions.

Atmospheric scientists played key roles in numerous field campaigns during the year that began with the Mid-latitude Continental Convective Clouds Experiment (MC3E). The experiment sampled a broad variety of precipitation types and intensities, including many cases of severe thunderstorm systems, using two aircraft (NASA/ER-2 and UND/Citation) and an extensive array of ground instruments over a six-week period. The Earth Venture-1 DISCOVER-AQ campaign began on July 1 and provided a sequence of Friday/Saturday remote-sensing aircraft flights to contrast pollution conditions on a weekday versus a weekend, albeit a holiday weekend. The mission was extremely successful in capturing a wide variety of air quality

conditions (ranging from very clean to very polluted) over the month of July. The ECO-3D campaign took place during 3 weeks in August to September, 2011 using the NASA P-3 aircraft and covered areas as far north as Quebec, Canada and as far south as the Florida Everglades. The instrument suite provided novel, complimentary information on forest canopy structure properties and acquired data in order to assess new methods for forest biophysical parameter estimation including above-ground biomass. Looking forward toward 2012, the Hurricane and Severe Storm Sentinel (HS3) investigation completed its 2011 test flights in preparation for deployment in September 2012. Two Global Hawk aircraft will carry out one-month-long missions during the 2012 Atlantic hurricane season.

Atmospheric scientists received many top professional honors and appointments during the year. William Lau was selected as a member of a new National Academy of Science Committee to study the impact of climate change on accelerated melting of Himalayan glaciers and impacts on downstream population. Paul Newman, Chief Scientist for Atmospheres, has been named a Fellow of the American Meteorological Society. Election to the grade of "Fellow" serves as a recognition of outstanding contributions to the atmospheric sciences or related oceanic or hydrologic sciences during a substantial period of years. Lazaros Oreopoulos accepted an invitation to serve a two-year term representing Code 610 in the Science Director's Council (SDC). Matt McGill and Dennis Hlavka shared in a prestigious Naval Research Laboratory (NRL) award for an outstanding publication, as co-authors, at the annual NRL awards banquet in March. Joe Munchak (612/ESSIC) was selected to receive the American Meteorological Society's Robert Leviton Award for his paper A Modular Optimal Estimation Method for Combined Radar–Radiometer Precipitation. Jim Irons delivered a keynote address for a Tribal College and University workshop at Haskell Indian Nations University, Lawrence, KS. The workshop was part of a student "externship" program sponsored by NASA's Tribal College and Universities Project.

August 15, 2011 marked the 20th anniversary of the Meteor-3/TOMS launch from the then Soviet Union and was the first flight of a NASA instrument on a Russian spacecraft. The anniversary was commemorated by an exchange of congratulatory letters between the respective project teams.

I am pleased to welcome research scientists Alexei Lyapustin, Dong Wu, and Walt Petersen to the GSFC atmospheric community. Alexei brings expertise in multi-instrument remote sensing of aerosol and surface properties. Dong has published widely in remote sensing, cloud-aerosol interactions, multi-angle techniques, sub-millimeter wind retrieval, Doppler winds, and others. Walt will manage and conduct ground and airborne remote-sensing studies of precipitation physics in support of the pre-launch Global Precipitation Management (GPM) retrieval algorithm development and the post-launch, satellite ground validation from our Wallops Island site.

This report is being published in two media: a printed version and an electronic version on our Atmospheres Web site, http://atmospheres.gsfc.nasa.gov/. We continually redesign our site to make it more useful for our scientists, colleagues, and the public. We welcome comments on this report and on the material displayed on our Web site.

Deputy Director for Atmospheres

Earth Sciences Division, Code 610

May 2012

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1. INTRODUCTION

Atmospheric research in the Earth Sciences Division (Code 610) consists of research and technology development programs dedicated to advancing knowledge and understanding of the atmosphere and its interaction with the climate of Earth. The Division's goals are to improve understanding of the dynamics and physical properties of precipitation, clouds, and aerosols; atmospheric chemistry, including the role of natural and anthropogenic trace species on the ozone balance in the stratosphere and the troposphere; and radiative properties of Earth's atmosphere and the influence of solar variability on the Earth's climate. Major research activities are carried out in the Mesoscale Atmospheric Processes Laboratory, the Climate and Radiation Laboratory, the Atmospheric Chemistry and Dynamics Laboratory, and the Wallops Field Support Office. The overall scope of the research covers an end-to-end process: starting with the identification of scientific problems, observation requirements for remote-sensing platforms, technology and retrieval algorithm development; leading to flight projects and satellite missions; and eventually, resulting in data processing, analyses of measurements, and dissemination from flight projects and missions. Instrument scientists conceive, design, develop, and implement ultraviolet, infrared, optical, radar, laser, and lidar technology to remotely sense the atmosphere. Members of the various Laboratories conduct field measurements for satellite sensor calibration and data validation, and carry out numerous modeling activities. These modeling activities include climate model simulations, modeling the chemistry and transport of trace species on regional-to-global scales, cloud resolving models, and developing the next-generation Earth system models. Satellite missions, field campaigns, peer-reviewed publications, and successful proposals are essential at every stage of the research process to meeting our goals and maintaining leadership of the Earth Sciences Division in atmospheric science research. Figure 1.1 shows the 18-year record of peer-reviewed publications and proposals among the various Laboratories.

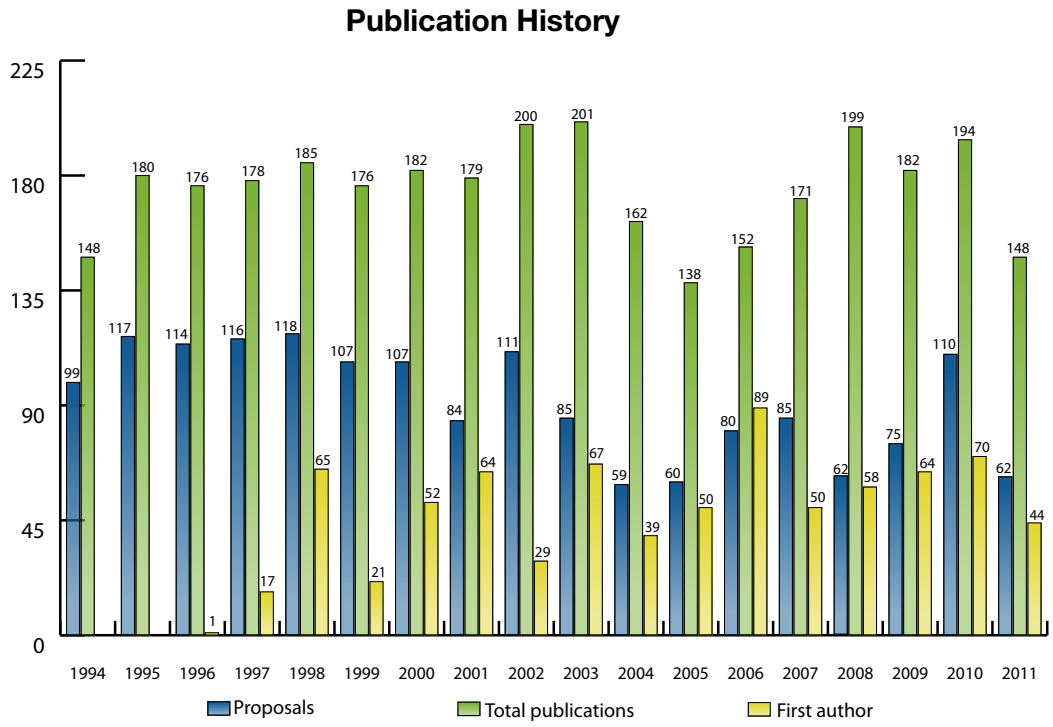

Figure 1.1: Number of proposals and referred publications by Atmospheric Sciences members over the years. The green bars are the total number of publications and the blue bars the number of publications where a Laboratory member is first author. Proposals submitted are shown in yellow

This data shows that the scientific work being conducted in the Laboratories is competitive with the work being done elsewhere in universities and other government agencies. The newly created office of Deputy Director for Atmospheric Research will strive to maintain this record by rigorously monitoring and promoting quality while emphasizing coordination and integration among atmospheric disciplines. Also, an appropriate balance will be maintained between the scientists' responsibility for large collaborative projects and missions and their need to carry out active science research as a principal investigator. This balance allows members of the Laboratories to improve their scientific credentials, and develop leadership potentials.

Interdisciplinary research is carried out in collaboration with other laboratories and research groups within the Earth Sciences Division, across the Sciences and Exploration Directorate, and with partners in universities and other government agencies. Members of the Laboratories interact with the general public to support a wide range of interests in the atmospheric sciences. Among other activities, the Laboratories raise the public's awareness of atmospheric science by presenting public lectures and demonstrations, by making scientific data available to wide audiences, by teaching, and by mentoring students and teachers. The Atmosphere Laboratories make substantial efforts to attract and recruit new scientists to the various areas of atmospheric research. We strongly encourage the establishment of partnerships with Federal and state agencies that have operational responsibilities to promote the societal application of our science products. This report describes our role in NASA's mission, provides highlights of our research scope and activities, and summarizes our scientists' major accomplishments during calendar year 2011. The composition of the organization is shown in Figure 1.2 for each Code. This report is published in a printed version with an electronic version on our atmospheres Web site, http://atmospheres.gsfc.nasa.gov/.

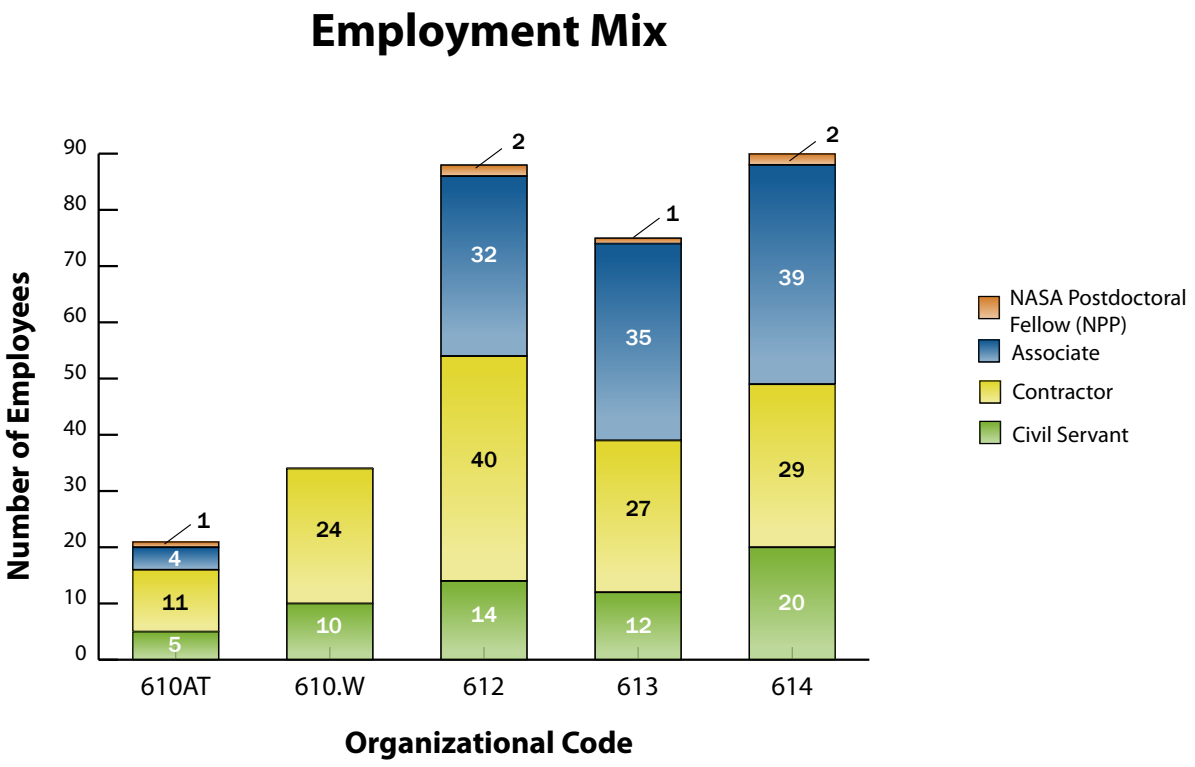

Figure 1.2: Employment composition of the members of Atmospheric Sciences.

2. SCIENCE HIGHLIGHTS

Atmospheric research at Goddard has a long history (more than 40 years) in Earth Science, studying the atmospheres of both the Earth and the planets. The early days of the TIROS and Nimbus satellites (1960's–1970's) emphasized ozone monitoring, Earth radiation, and weather forecasting. Planetary atmosphere research with the Explorer, Pioneer Venus Orbiter, and Galileo missions was carried out until around 2000. In the recent years, EOS missions have provided an abundance of data and information to advance knowledge and understanding of atmospheric and climate processes. Basic and crosscutting research is carried out through observation, modeling, and analysis. Observation data is provided through satellite missions as well as in-situ and remote-sensing data from field campaigns. Scientists also focus their efforts on satellite mission planning and instrument development. For example, feasibility studies and improvements in remote-sensing measurement design and technology are underway in preparation for the planned decadal mission recommendations made in the Decadal Survey by the National Academy of Sciences in 2007 (http://www.nap.edu/catalog/11820.html). The following sections summarize some of the scientific highlights for the year 2011 with the contributor(s) named at the end of each summary. Additional highlights and other information may be found at the website: http://atmospheres.gsfc.nasa.gov.

2.1. Mesoscale Atmospheric Processes Laboratory

The Mesoscale Atmospheric Processes Laboratory seeks to understand the contributions of mesoscale atmospheric processes to the global climate system. The Laboratory conducts research on the physical and dynamic properties, and on the structure and evolution of meteorological phenomena—ranging from synoptic scale down to micro-scale—with a strong focus on the initiation, development, and effects of cloud and precipitation. A major emphasis is placed on understanding energy exchange and conversion mechanisms, especially cloud microphysical development and latent heat release associated with atmospheric motions. The research is inherently focused on defining the atmospheric component of the global hydrologic cycle, especially precipitation, and its interaction with other components of the Earth system. The Laboratory also plays a key science leadership role in the Tropical Rainfall Measurement Mission (TRMM), launched in 1997 and still operating, and in developing the Global Precipitation Measurement (GPM) mission concept. Another central focus is developing remote-sensing technology and methods to measure aerosols, clouds, precipitation, water vapor, and winds, especially using active remote sensing (lidar and radar).

Highlights of Laboratory research activities carried out during the year are summarized below.

Laboratory research has played a crucial role in assuring the scientific integrity of the GPM mission that is scheduled to launch in 2013. A study was carried out using a 10-year climatology spanning 1998–2007 of radar-gauge assimilated hourly rain data from the North American Land Data Assimilation System (NLDAS-2). This climatology of the rainfall diurnal cycle will be a new benchmark for validating the upcoming GPM mission. Another contribution to GPM was the demonstration of a unique capability to study the dynamics of hurricane genesis and intensification processes. Horizontal winds were derived from HIWRAP within precipitation and cloud regions over the long duration of a Global Hawk flight. This is a capability filled by neither current satellites nor manned aircraft and will be used for GPM validation. A theoretical investigation developed physically based precipitation retrieval algorithms (both rain and snow) to understand the physical relationships between satellite observations of the Earth and the state of the atmosphere and surface within the field of view. This work is extremely relevant for retrievals of falling snow from GPM's Microwave Radiometer (GMI) with channels from 10 to 183 GHz. Precipitation, in all forms, is a critical link in the Earth's global water and energy cycles. ***(Toshihisa Matsui, Gerry Heymsfield, and Gail Skofronick-Jackson)***

Science Highlights

A study was carried out to improve our understanding of how and why the global water (and energy) cycle, specifically global precipitation and tropospheric water vapor content, responds differently to El Niño Southern Oscillation (ENSO) and volcano-related climatic perturbations**.** Using satellite observations, variations associated with ENSO and volcanic eruptions were identified in several key physical components (such as surface temperature and columnar water vapor) and further compared in their global and tropical fields. The study was the first step for assessing our current knowledge of global climate changes specifically in the global water cycle. The results will aid in interpreting global-warming–related processes and features, which may already have occurred during the past three decades. ***(Guojun Gu and Robert Adler)***

Creating an improved representation of the water and energy cycles is also critical to global weather and climate simulation. The simulation of the diurnal cycle has long been recognized as a problem with traditional global climate models (GCM) using parameterized moist processes. The Goddard Multi-scale Modeling Framework-Land Information System (MMF-LIS) shows promise for improving the simulation

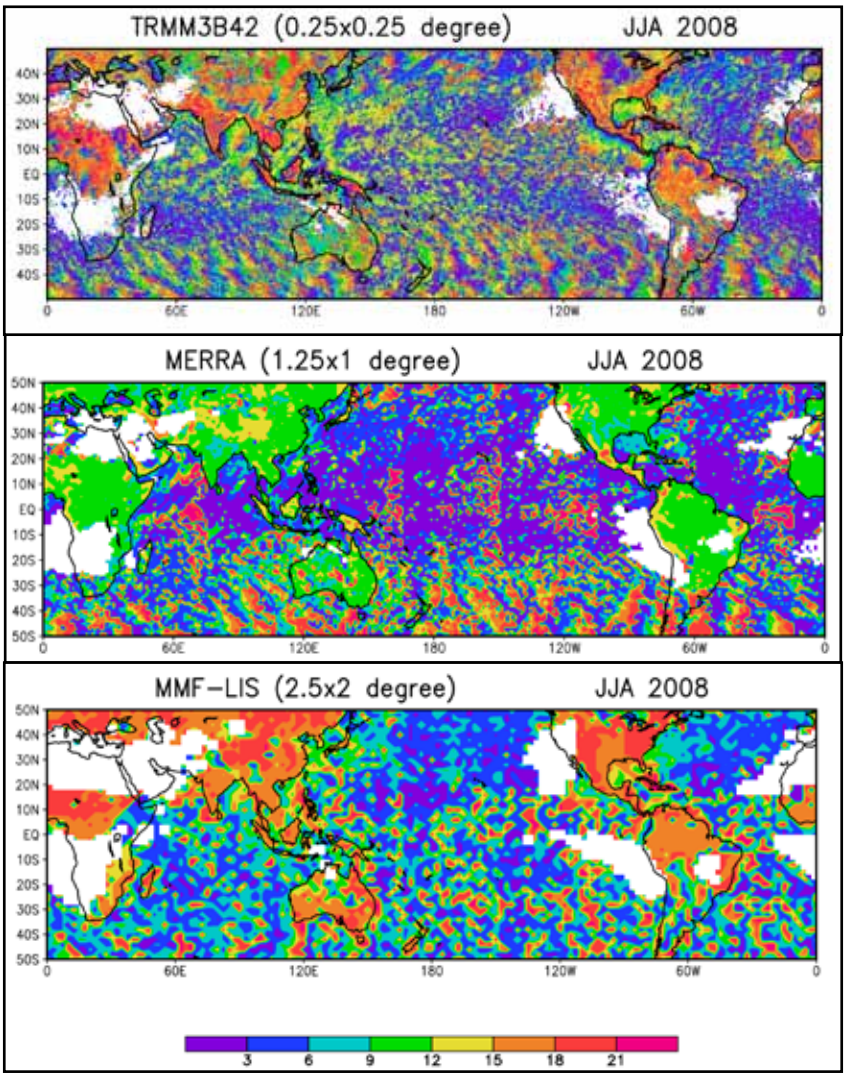

Figure 2.1: Significamt improvements in simulation of the diurnal cycle over land by the MMF-LIS

of global precipitation—and thus atmospheric circulations—at multiple scales. Figure 2.1 demonstrates a significant improvement, particularly over land, by the MMF-LIS. The MMF-LIS is a global modeling framework that substitutes multiple, cloud-resolving model arrays, which explicitly resolved convection, for the moist process parameterizations. Geographical distribution of the local solar time (LST) for non-drizzle precipitation frequency maxima between June and August 2008 are shown with (top) TRMM 3B42 product at $0.25° \times 0.25°$ resolution, (middle) MERRA reanalysis at $1° \times 1.25°$, and (bottom) free-running MMF-LIS simulation at $2° \times 2.5°$. Color bars indicate the LST (h), and blank regions indicate no or light rain. The MMF-LIS-simulated timings of maximum diurnal precipitation are in good agreement with TRMM observations over land (in the late afternoon and early evening) and over ocean (in the early morning with large variability). The MERRA reanalysis places the maximum phase too early over land, as compared to TRMM. The cloud-resolving component of the MMF-LIS, called the Goddard Cumulus Ensemble, improves upon the build-up and release of convective available potential energy in the continental boundary layer compared to cumulus parameterizations typically used in GCMs. The MMF-LIS framework is discussed in detail in Section 3.4.1. ***(Karen Mohr and Wei-Kuo Tao)***

Cloud-resolving models (CRM) provide fundamental insights into cloud processes and budgets, and are used to create cloud datasets for retrieval algorithms. A bulk scheme using statistical comparisons (e.g., Probability Density Functions) with radar and satellite data provided a more rigorous (but not perfect, since reflectivity depends on multiple hydrometeor species) means to evaluate cloud physics and identify and improve CRM biases and thereby their overall accuracy. ***(Stephen Lang, Wei-Kuo Tao, and Xiping Zeng)***

Aerosol-cloud interactions affect the aerosol physical properties (i.e., size) and in turn their influence on solar radiation and cloud formation and precipitation. To improve cloud screening procedures, an effort to accurately measure both aerosol and cloud optical thickness while avoiding thin, cirrus cloud contamination in AOT measurements was completed and will result in a new AERONET procedure for thin cirrus clouds. This improvement in thin cirrus bias screening will benefit passive AOT retrievals for missions such as MODIS on Aqua and Terra, as well as future aerosol missions such as PACE and ACE. ***(Ellsworth Welton, Jingfeng Huang, Brent Holben and Si-Chee Tsay)***

Water vapor is important to atmospheric chemistry, radiation, dynamics, and cloud development. Water vapor amounts are anticipated to increase with rising global temperatures. Increases in stratospheric water vapor can lead to cooling of the stratosphere and warming of the troposphere. A study and simulation was conducted to determine what measurements are needed to reveal trends in atmospheric water vapor most efficiently and quickly. There is significant variation in the time to detect trends for different measurement frequencies and amount of random error. The results showed that it is more important to increase the frequency of measurement than to decrease the uncertainty of the measurement. For example, the number of years needed to detect a trend can be reduced from 36 to 12 years, with the same uncertainty, by increasing sampling frequency from 1 to 30 times per month. ***(David Whiteman, Kevin Vermeesch, Luke Oman and Elizabeth Weatherhead)***

Observation of the wind field plays an important role in understanding the dynamics of the atmosphere on all scales, global and mesoscale. The Tropospheric Wind Lidar Technology Experiment (TWiLiTE) is a Doppler lidar system that measures vertical profiles of wind in clear air by measuring the Doppler shift of laser signal scattered back to the instrument by molecules. Recent engineering flights on NASA's ER-2 aircraft demonstrated the autonomous operational capabilities of the instrument and produced the first full tropospheric (0–20 km altitude) lidar wind profiles from an airborne platform. The TWiLiTE project advanced the technology readiness level of the wind lidar system on the roadmap to the Global 3D Winds Mission. ***(Bruce Gentry)***

An experimental algorithm to retrieve rainfall rates and median raindrop size (D_0) was applied to data from the Precipitation Radar (PR) and TRMM Microwave Imager (TMI) on NASA's Tropical Rainfall Measuring Mission Satellite. This combination of instruments allows a more accurate retrieval of these two parameters than is possible with either instrument alone. This knowledge is important for improving radar-based rainfall estimates (a 25% change in D_0 is equivalent to a 90% change in rain rate). This research will be greatly enhanced by the data from GPM, with the much smaller error in raindrop size retrieval due to the dual-frequency precipitation radar. In addition to providing better instantaneous measurements, these data will be able to identify any long-term biases in the TRMM-based climatology, especially if there is an overlap period in the operations of the two satellites. ***(S. Joseph Munchak, C. Kummerow, and G. Elsaesser)***

Laboratory scientists continue to actively research hurricane formation, structure, and precipitation processes. We also use models and TRMM satellite data to study the organization of precipitation in winter storms and the mechanisms responsible for that organization. Laboratory research will continue to play a crucial role supporting the upcoming GPM mission.

2.2. Climate and Radiation Laboratory

Understanding the Earth's climate system and how it is affected by human activities now and in the future is one of the most pressing issues facing humankind. This has been the driving force behind many of the activities in the Climate and Radiation Laboratory. Accordingly, the Laboratory has made major scientific contributions in five key areas: hydrologic processes and climate, aerosol-climate interaction, clouds and radiation, model physics improvement, and technology development. Examples of these contributions can be found in the list of refereed articles in Appendix II and in the material updated regularly on the Code 613 Laboratory Web site: http://atmospheres.gsfc.nasa.gov/climate/.

The Laboratory's main satellite observational efforts have included MODIS and MISR algorithm development and data analysis, SORCE solar irradiance (both total and spectral) data analysis and modeling, and TRMM and ISCCP data analysis. Leadership and participation in science and validation field campaigns have provided key measurements, as well as publications and presentations. Laboratory scientists served in key leadership positions on international programs, panels, and committees, served as project scientists on NASA missions and PI's on research studies and experiments, and made strides in many areas of science leadership, education, and outreach. Some of the Laboratory research highlights for the year 2011 are described below. They cover aerosol-cloud-precipitation interactions, aerosol effects on climate, reflected solar radiation, land–atmosphere feedback, polar region variations, and hydrological cycle changes. The Laboratory also carries out an active program in mission concept developments, instrument concepts and systems development, and Global Climate Models (GCMs). The "Projects" link on the Climate and Radiation Laboratory Web site contains recent significant findings in these and other areas.

The study of aerosols is important to Laboratory scientists for many reasons:

1) Their direct and indirect effects on climate are complicated and not well-quantified; 2) Poor air quality due to high aerosol loadings in urban areas has adverse effects on human health; 3) Transported aerosols provide nutrients such as iron (from mineral dust and volcanic ash), important for fertilizing parts of the world's oceans and tropical rainforests; and 4) Knowledge of aerosol loading is important for determining the potential yield from green solar energy sources.

In order to improve the knowledge of aerosol effects on climate, a group of scientists derived the new aerosol dataset from Sea-viewing Wide Field-of-view Sensor (SeaWiFS) measurements. The 13-year time series (1997–2010) including much of the strong 1997–1998 El Niño period. It also includes aerosol optical depth (AOD, a measure of atmospheric turbidity) in the mid-visible range of the spectrum (550 nm), and the Angstrom exponent, linked to particle size. Intercomparisons with other satellite and model datasets will enable improvements in both through identification of reasons for differences and increased confidence in results when results are consistent and understood. This dataset will prove to be a valuable asset in this process. ***(Christina Hsu, Corey Bettenhausen, and Andrew Sayer)***

Aerosol-cloud-precipitation interactions are a key set of unresolved processes in our understanding of the climate system. Laboratory scientists provided the first observational evidence to a long-standing debate on the role of aerosols in determining cloud electrification properties. They showed that aerosols could fundamentally alter cloud electrification processes. This was accomplished by observing SO_2 and aerosol concentrations from OMI and MODIS, respectively, downwind of the Anatahan volcano in the Northern Mariana Islands. When active in 2005, it increased aerosol concentrations downwind by 60%. As a result the number of lightning flashes increased by 150% above the usual level for the area. This solves a long-standing mystery surrounding tall towers of cumulonimbus over tropical warm waters where lighting is seldom observed. The theory behind the lighting increase due to aerosols can be summarized by the following chain reaction: aerosols slow down the rain process, enhance the vigor inside clouds, create more changes, and produce more lighting. ***(Tianle Yuan, Lorraine Remer, Kenneth Pickering, and Hongbin Yu)***

Aerosols are an essential ingredient for cloud formation and their amount can significantly change cloud properties. Kilauea is a volcano on the Big Island of Hawaii, and it was constantly emitting sulfur dioxide gases during the summer of 2008. The resulting aerosol particles observed from MODIS showed a large-scale plume downwind of the Hawaiian Islands. Laboratory scientists showed that these aerosol particles decrease cloud droplet size, increase cloud brightness, and ultimately enhance cloud fraction. For the first time observations of large-scale increases in cloud fraction resulting from aerosol-cloud interactions were shown. This was made possible with observations by a suite of instruments onboard the NASA A-Train satellites. The theory and observational evidence are detailed in Yuan et al. (2011) and can be summarized in the following chain reaction: aerosols increase the number of cloud droplets and decrease their sizes, suppress drizzle formation, make clouds brighter and larger and finally increase cloud coverage. Direct satellite observations suggest as much as 20 W m^{-2} more solar energy is reflected back to space as a result of aerosol increasing cloud brightness and coverage. ***(Tianle Yuan, Lorraine Remer, and Hongbin Yu)***

Interest in volcanic ash plume evolution centers on aviation safety as well as cloud formation and climate interactions. Near-source wildfire smoke, desert dust, and volcanic ash plume heights are key inputs to models that predict plume evolution, and aerosol impact on regional environment and global climate. Iceland's Eyjafjalljökull volcano erupted repeatedly between April 14 and May 23, 2010, sending ash plumes across the skies of Europe, disrupting air traffic, and stranding travelers for up to several weeks. During the early eruptions, much of European airspace was shut down; by early May, selective closures allowed many more flights to proceed, vastly reducing the impact on society. A study of these events showed that the multi-angle–imaging, plume-height mapping capability based on stereo-derived, reflecting-level heights of MISR complemented lidar height measurements, which are generally more sensitive to height distribution for thinner aerosol layers, but provide only a single curtain of data rather than regional height coverage. These results demonstrate one of the significant contributions a next-generation, multi-spectral, multi-angle, polarimetric imager duplicating and enhancing the MISR capabilities will make to Decadal Survey ACE mission. ***(Ralph Kahn)***

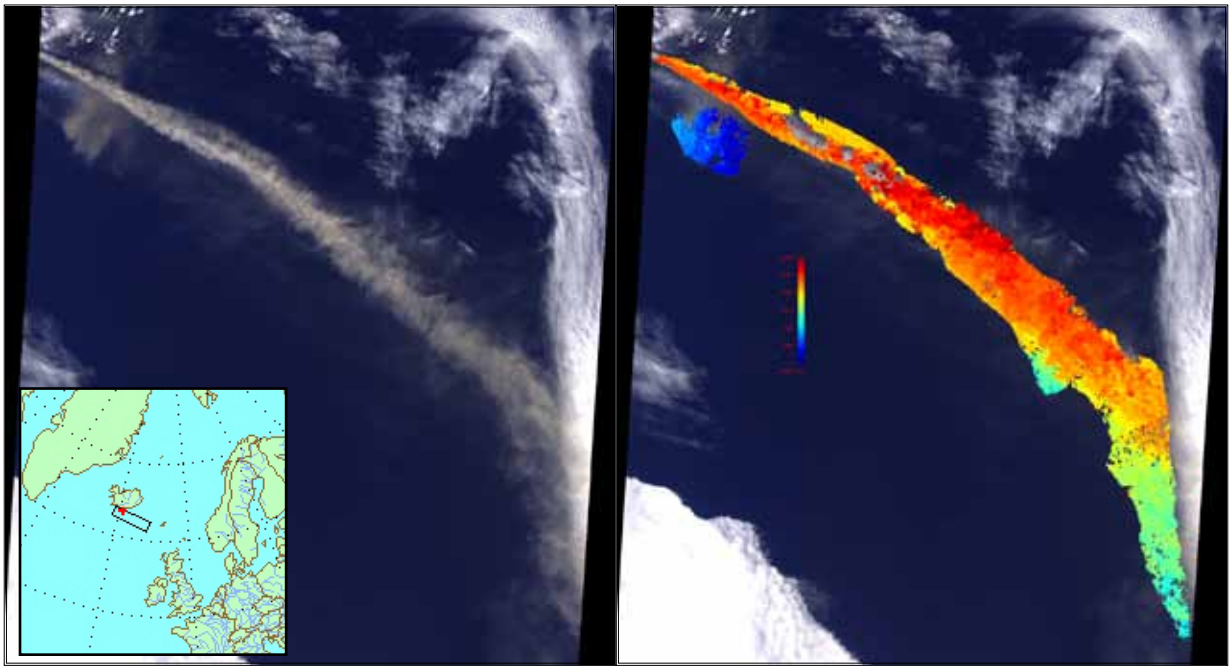

*Figure 2.2: 07 May 2010 12:39 UT—The Multi-angle Imaging SpectroRadiometer (*MISR*) instrument aboard the* NASA *Earth Observing System's Terra satellite captured the true-color, nadir-viewing image at left, along with eight other images at viewing angles ranging from +70° to −70° along a 380-km-wide ground track. Aerosol amount and type, as well as plume vertical extent and ambient wind vectors, are derived from the* MISR *multi-spectral, hyper-stereo observations. The image at right shows plume height derived for this event using the* MINX *algorithm. Two plumes appear: More than 400 km of the main plume falls within the* MISR *field-of-view; it is injected to about 6 km and descends to about 3 km toward the southeast. The second, smaller plume is remobilized ash residing near-surface. The volcano itself is at the upper left in these images (see inset map in the left image), and north is roughly toward the top.*

The variations of rainfall and soil moisture, and land-atmosphere feedback processes as well as the aerosol-cloud-precipitation interactions are important physical processes in the climate system. A prior study provided observational evidence that torrential rain over Pakistan during summer of 2010 was triggered by Rossby wave response to prolonged atmospheric blocking in western Russia and fueled by enhanced moisture transport from the Bay of Bengal and the northern Arabian Sea. Evidence was shown that each event was amplified through feedback mechanisms that involved land-atmosphere interaction for the Russian heat wave and the development of mid-tropospheric cyclones for the heavy rain events over northern Pakistan. These observations are consistent with model projection, which show that unusual and extreme weather events tend to occur more frequently in a warmer climate. In this case, a pair of extreme events—the Russian heat wave versus the Pakistan flood—with opposite polarity and separated by vast distances was actually connected by atmospheric Rossby wave trains initiated by intense atmospheric blocking over western Russia. ***(William Lau and Kyu-Myong Kim)***

Understanding aerosol radiative effects and aerosol-cloud interactions is critical for reducing uncertainties regarding human impacts on climate. A laboratory study of how aerosol particles change in the vicinity of clouds provided the first observational evidence of near-cloud particle changes being sufficiently strong to alter global statistics of aerosol populations. The study showed that areas near clouds occupy a large segment of all clear-sky regions, which implies that understanding aerosols near clouds is essential for understanding the role of aerosols in our climate. Due to physical processes, such as swelling in humid air, aerosol particles around clouds change in a wide transition zone that covers over half of all clear-sky

areas. The finding that particle changes in the transition zone are sufficiently prevalent to impact even global statistics highlights the need to better understand these changes and consider both of them when interpreting satellite data and climate simulations. One of the ultimate goals is to help reduce some of the largest sources of uncertainties in understanding human impacts on climate: aerosol-cloud interactions and aerosols reflecting or absorbing sunlight. ***(Alexander Marshak)***

Changes in the tropical hydrological cycle can be expected to cause a shortage or excess of precipitation in many regions that, in turn, would impact all life on Earth. Laboratory scientists examined decadal trends of the tropical hydrological cycle to determine if such trends can provide an observation-based benchmark for model predictions of the ongoing climate change. The results show 1) intensification and weakening of tropical precipitation—showcasing the "wet-getting-wetter, dry-getting-dryer" phenomena; 2) pole-ward shift of the subtropical dry zones in June, July, and August (JJA) in the Northern Hemisphere as well as JJA and September, October, and November (SON) in the Southern Hemisphere; and 3) significant pole-ward migration of cloud boundaries of Hadley cell and plausible narrowing of the high cloudiness in the Intertropical Convergence Zone (ITCZ) region in some seasons. These trends indicate a strengthening of the tropical hydrological cycle with intensification of extremes of dry and wet conditions. This research is directly relevant to two of NASA's Earth Science focus areas: water and energy cycle, and climate variability and climate change. ***(Yaping Zhou)***

Hailstorm and tornado activity increases in the middle of the work week (Tuesday-Thursday) compared to weekends. Rosenfeld and Bell showed this in a recently published paper in the *Journal of Geophysical Research*. Weekly cycles in weather behavior are a clear sign of human influence on our climate. This weekly cycle is believed to be caused by the well-known changes in pollution levels associated with the day of the week (e.g. transportation). Aerosol pollution decreases the size of water droplets coalescing in clouds. They are lighter and do not fall out as rain, but instead rise to much higher altitudes where they freeze and release additional heat ("latent heat of fusion"). This invigorates the storm and produces more ice aloft. Based on numerical model simulations, Rosenfeld and Bell postulate that storms, amped up by pollution, nevertheless produce weaker cold pools at their base. Tornados develop less easily when a cold, rapidly-moving pool forms beneath the storm. By weakening cold-pool formation, pollution may lead to storms with better chances of forming a tornado than is the case for storms formed in clean air. This research is highly relevant to several of the challenges contained in the *Decadal Survey*: climate changes, as reflected in changes in severe storm behavior and in shifts of rainfall patterns; and weather forecasting. It underlines the need for monitoring aerosol concentrations in the atmosphere on a continuing basis. ***(Daniel Rosenfeld and Thomas Bell)***

The computer codes that calculate the energy budget of solar and thermal radiation in Global Climate Models (GCMs), our most advanced tools for predicting climate change, have to be computationally efficient in order to avoid imposing an undue computational burden to climate simulations. By using approximations to gain execution speed, these codes sacrifice accuracy compared to more accurate, but much slower, alternatives. International efforts to evaluate the approximate models have taken place in the past, but they have suffered from the drawback that the accurate standards were not themselves validated. In a recent paper, Oreopoulos et al. (2012) summarized the main results of the first phase of an effort called "Continual Intercomparison of Radiation Codes" (CIRC) where the cases chosen to evaluate the approximate models were based on observations and where it was ensured that the accurate models perform well when compared to solar and thermal radiation measurements. The CIRC project has analyzed submissions by 11 solar and 13 thermal infrared codes relative to accurate reference calculations obtained by so-called "line-by-line" radiation codes. It has demonstrated that, while performance of the approximate codes continues to improve, significant issues still remain to be addressed for satisfactory performance within GCMs. By identifying and quantifying shortcomings, CIRC aspires to establish performance standards to objectively assess radiation code quality and contribute to the development of improved radiation parameterizations. This effort is

endorsed by international organizations such as the Global Energy and Water-cycle Experiment (GEWEX) and the International Radiation Commission. CIRC has a dedicated website, http://circ.gsfc.nasa.gov, where interested scientists can freely download data for testing their codes and obtaining more information about the effort's modus operandi and objectives. ***(Lazaros Oreopoulos)***

The Beaufort and East Siberian Sea (BESS) showed a large increase in surface air temperature in the recent decade during the months of September through November. Causes of the warming remain unclear; but increased absorption of summer solar radiation and autumn low-cloud formation has been suggested as a positive ice-temperature-cloud feedback in the Arctic. Laboratory scientists using Terra/MISR data observed a significant increase of low cloud cover in October during 2000–2010. The regions with the largest October low-cloud increase collocated with areas where most sea ice loss occurred in September. The observed increase of October low-cloud cover over the Arctic Ocean supports the hypothesis that low clouds have a positive feedback to sea ice loss by warming SAT during late summer and autumn, and thus reducing perennial ice pack formation. Monitoring and understanding the rapid climate changes in the polar region is one of NASA's strategic goals in climate research. ***(Dong Wu and Jae N. Lee)***

Currently, large uncertainties in climate modeling exist because of the complexity of aerosol processes and incomplete understanding of their interactions with the climate system [IPCC, 2007]. Aerosol absorption is one of the most important and least known climate-forming factors. Detection and characterization of trends in anthropogenic aerosol absorption is critical for improving our understanding of aerosol radiative and climate effects. Laboratory scientists determined that satellite retrievals have very limited ability to evaluate aerosol absorption from multi-angle (MISR) or UV (OMI) measurements. Therefore, a combination of MODIS and AERONET data was used to demonstrate a measurable reduction of the aerosol absorption over Beijing during 2007–2010 as compared to the previous five years, most probably caused by the regulation of black carbon (BC) emissions. The scientists used the Multi-Angle Implementation of Atmospheric Correction (MAIAC), a new MODIS algorithm providing aerosol and land reflectance properties. Two independent methods based on the time series analysis of a) MODIS/AERONET AOT data, and b) AERONET SSA (single-scattering albedo) data, produced similar results, which are in qualitative agreement with in situ chemical composition analysis [Okuda et al., 2011] and IASI CO data. The timing of these changes is correlated with the extensive measures adopted by the Chinese government to improve air quality in Beijing in advance of the 2008 Olympic Games. The importance of studying this interaction is highlighted in the *Decadal Survey* and is a goal for future NASA missions such as ACE. ***(Alexei Lyapustin, Alexander Smirnov, Brent Holben, Ralph Kahn, Mian Chin, D. Streests, et al.)***

Finally, Laboratory scientists will continue to use models, surface observations, field campaigns, and satellite data to study and better understand aerosol effects and interactions on regional and global systems and Earth's climate, solar radiation and reflection, mission studies, instrument system developments; as well as render support to the decadal study goals and objectives. Members will also continue to participate in education and outreach activities and serve on panels and committees supporting the scientific community.

2.3. Atmospheric Chemistry and Dynamics Laboratory

The Atmospheric Chemistry and Dynamics Laboratory conducts research that includes both the gas-phase and aerosol composition of the atmosphere. Both areas of research involve extensive measurements from space to assess the current composition and to validate the parameterized processes that are used in chemical and climate prediction models. This area of chemical research dates back to the first satellite ozone missions, and the Division has had a strong satellite instrument, aircraft instrument, and modeling presence in the community. Both the EOS Aura satellite and the OMI instrument U.S. Science team come from this group. The Laboratory also is a leader in the integration and execution of the NPP mission, and

is also providing leadership for the former NPOESS, now the newly reorganized Joint Polar Satellite System (JPSS). In addition, this group has developed a state-of-the-art chemistry-climate model, in collaboration with the Goddard Modeling and Analysis Office (GMAO). This model has proved to be one of the best performers in a recent international chemistry-climate model evaluation for the stratosphere.

Highlights of Laboratory research activities carried out during the year are summarized below.

The Laboratory continued to monitor the spread of volcanic eruptions, including the gaseous and aerosol clouds from a major explosive eruption of Indonesia's Merapi volcano on November 4–5, 2010. These eruptions were measured by A-train sensors on Aura/OMI and CALIPSO. Mount Merapi is positioned to have a major impact on climate cooling by reflecting sunlight since it is just 7.5 degrees south of the equator. Aura OMI and the NASA/NOAA Ozone Monitoring and Profiling Suite (OMPS) on NPP will continue monitoring volcanic and anthropogenic SO_2 from space to detect trends in volcanic and anthropogenic aerosol precursors and allow more frequent monitoring of volcanic and anthropogenic SO_2 pollution over North and South America. ***(Nickolay Krotkov)***

We published the first global maps of fluorescence from space using high spectral-resolution observations from the Japanese GOSAT in 2010. These fluorescence measurements are capable of showing plant stress before reductions in greenness takes place and are, therefore, important to precision farming, forestry, and carbon assessment. Since then, we have refined our approach by developing methods to account for the subtle and complex effects of instrumental artifacts. We have also detected what we believe is vegetation fluorescence from the SCIAMACHY satellite instrument on ESA's EnviSat. The SCIAMACHY measurements were made at a very long wavelength not optimal for fluorescence measurements. Though not optimal, the SCIAMACHY results indicate that fluorescence can be detected with potentially lower cost (lower spectral resolution) instrumentation as compared with expensive high-spectral-resolution sensors.

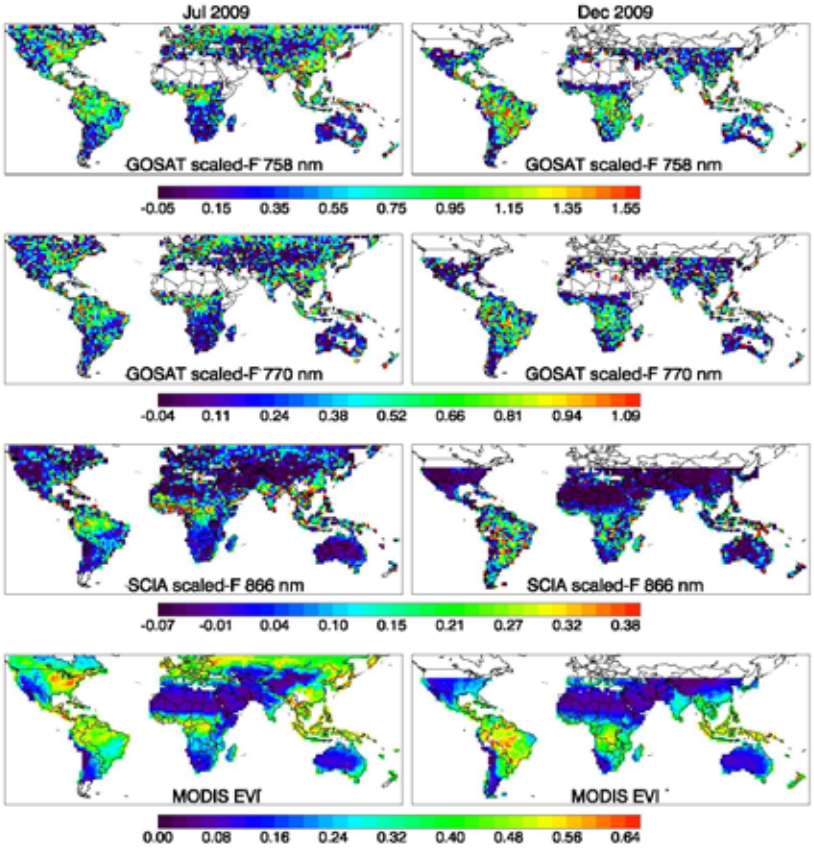

*Figure 2.3: Satellite-derived fluorescence for July 2009 (left) and January 2009 (right) shows the expected seasonal variation in photosynthetic activity (high activity in the northern hemisphere in July versus high activity in the southern hemisphere latitudes in January). As a reference, the bottom row shows the Enhanced Vegetation Index (*EVI*) derived from* MODIS *that displays similar seasonal behavior. Fluorescence shown is normalized by incoming radiance (scaled-F) and derived from* GOSAT *at two different wavelengths (top two rows) and from* SCIAMACHY *(*SCIA*, 3rd row) at a longer wavelength.*

The SCIAMACHY data cover more than eight years (2003 through 2011). A detailed climatology has been developed from those data. Laboratory measurements conducted at Goddard confirm that there is a small fluorescence signal at the SCIAMACHY measured wavelength but the measurements have not isolated the fluorescing compound.

Our research showed that fluorescence information is complementary to that provided by popular vegetation indices based on satellite reflectance data. This research will benefit future satellite missions specifically designed to measure vegetation fluorescence and other planned missions targeted for accurate trace-gas measurements such as the NASA Orbiting Carbon Observatory 2 (OCO-2) whose measurements are impacted by fluorescence. OCO-2 should provide improved fluorescence measurements. In addition, fluorescence data may ultimately be used toimprove global carbon models (***Joanna Joiner, Yasuko Yoshida, Alexander Vasilkov, Elizabeth Middleton, Petya Campbell, Lawrence Corp***)

Stratospheric ozone is strongly impacted by the greenhouse gases (GHGs) CO_2, CH_4, and N_2O, and man-made ozone depleting substances (ODSs) containing chlorine (Cl) and bromine (Br). Simulations with the GSFC two-dimensional model illustrated the individual long-term impacts of CO_2, CH_4, N_2O, and the ODSs on global total column ozone. These simulations indicated that all four perturbations would have substantial impacts on ozone during the 21st century, with changes of −2 to +4% by 2100, relative to 1850. CO_2 loading, which cools the stratosphere and reduces the ozone chemical loss rates, has the largest individual effect, causing a 4% increase over the 1850–2100 time period. The combined impact of all perturbations results in ozone amounts that are 1.5% larger in 2100 compared to 1850 and 1950. This has important implications for global climate and surface UV. This work shows the importance of man-made compounds in controlling the past and future changes in ozone. ***(Eric Fleming and Charles Jackson)***

Laboratory scientists investigated climate change in 1960–2060 time frame using a chemistry-climate model. The scientific questions to be addressed were: 1) What is the Antarctic ozone hole's role in climate change and 2) Are circulation changes in the troposphere and stratosphere related to each other? The results showed that the ozone hole significantly changes the stratospheric circulation and strongly impacts the tropospheric circulation pattern, causing a pole-ward movement of the tropical jet and strengthening the jet by 25%. These results imply that the projected ozone recovery in the latter half of this century will strongly impact future climate change. This research will also help to understand stratospheric ozone recovery and air pollution in a changing climate. (***Feng Li, Paul Newman, Anne Douglass, and Richard Stolarski)***

An important step was taken toward understanding the factors influencing the inter-annual variability of tropospheric ozone. The El Niño Southern Oscillation (ENSO) is the dominant mode of tropical variability on interannual timescales. Its influence extends beyond the thermal and dynamical into the chemical composition of the troposphere. Ziemke et al. [2010] found a dipole in tropospheric column ozone between the western and eastern Pacific region and identified this difference as an Ozone ENSO Index (OEI). An OEI computed using the Goddard Earth Observing System (GEOS) version 5 chemistry-climate model (CCM) reproduced the observed OEI and concluded that observed sea surface temperatures are dominant in driving the variability that controls this index. This work demonstrated the model's capability to represent the fundamental physical relationship between tropical sea surface temperature anomalies and ozone distribution changes in the tropical troposphere. (***Luke Oman, Jerry Ziemke, Anne Douglass, and Jose Rodriguez)***

Scientists have found new evidence for interactions between the ocean sea surface temperatures (SSTs) and the stratosphere. In March 2011, the Arctic stratosphere was much colder than usual, leading to severe polar ozone depletion. Dynamical conditions are known to cool the Arctic stratosphere in mid-winter but they do not explain the unusually cold Arctic stratosphere in March 2011. SSTs in the North Pacific were warmer than usual in the late winter in both 1997 and 2011. The positive phase of this "subarctic SST mode" is associated with a cooler Arctic stratosphere in March. This research is the first to show that extra-tropical SSTs also affect the Arctic stratosphere in late winter. (***Margaret Hurwitz, Paul Newman, and Chaim Garfinkel)***

Aerosols scatter and absorb solar radiation and play an important role in the energy balance of the earth-atmosphere system. A large fraction of the atmospheric aerosol load reaches the free troposphere and is frequently located above clouds. Laboratory scientists developed a method to measure the optical depth of absorbing smoke and dust aerosols located above clouds using satellite observations of upwelling radiation at two wavelengths in the near-UV spectral range. Aerosols above clouds absorb a fraction of the radiation reflected by the cloud and thus can produce a net warming effect of the atmospheric column A new satellite-based measuring technique will facilitate the study of several aspects of aerosol-cloud interaction and the accurate quantification of the direct radiative forcing effects of absorbing aerosols above clouds. (***Omar Torres, Pawan Bhartia,*** and ***Hiren Jethva)***

Further research showed the importance of solar-related processes on observed variations of the atmosphere. Solar eruptions in early 2005 led to a substantial barrage of charged particles on the Earth's polar atmosphere during the January 16–21 period. The solar protons created hydrogen - containing compounds, which led to polar ozone destruction. Aura Microwave Limb Sounder (MLS) observations showed that fairly substantial OH enhancements and HO_2 enhancements were caused by the Solar Proton Events (SPEs). This is the first time that SPE-caused HO_2 measured increases have been reported. The SPE-caused mesospheric ozone decreases up to 80%. It will be important to carry out further measurements of HO_X and NO_X constituents in order to understand the variations in ozone. (***Charles Jackman and Eric Fleming)***

Every year, Arctic column O_3 increases significantly during fall and winter due to transport from lower latitudes. The Aura MLS average for 2005–2010 shows stratospheric columns were 390 DU (Dobson Units). In 2011 O_3 columns were less than 260 DU at high latitudes. The 2011 polar vortex persisted through March, prohibiting the transport of O_3-rich air from lower to higher latitudes. This is atypical stratospheric meteorology. It is important for us to distinguish between low polar O_3 caused by Polar Stratospheric Cloud (PSC) catalyzed loss and inter-annual variability in stratospheric meteorology. ***(Susan Strahan)***

Quantifying the amount of clouds as a function of time of day (diurnal variations) is important for climate models and radiation budget estimates. Scientists assembled 32 years of NASA and NOAA satellite measurements (340 nm) into 5-degree zonal means and analyzed the zonal mean reflectivity. This produced the first UV reflectivity measurements of the diurnal variation of clouds and the data was then used to quantify the amount of energy reflected back into space due to clouds and aerosols as a function of time of day. For example, there are 25% more clouds at 7 a.m. than at noon for the zone containing land for 10–15 degrees south. These data can be put into global climate and energy balance models. Once the diurnal changes in cloud cover are measured, long-term, global cloud trends can be calculated from this data set and global heating and cooling rates can be inferred. ***(Gordon Labow, Jay Herman, Steve Lloyd, Matthew Deland, Liang-Kang Huang, Wenhan Qin, Juanping Mao, and David Larko)***

Laboratory scientists will continue research to understand the behavior of stratospheric and tropospheric ozone, aerosols, climate, and the trace gases that impact them.

2.4. Wallops Field Support Office

The Wallops Field Support Office provided instrumentation and scientific research expertise to several NASA missions and field efforts in 2011.

The NASA NPOL S-band dual-polarimetric radar went on its first field deployment after completing a major antenna system upgrade and subsequent testing in Colorado. The upgraded NPOL is now one of two research-grade, transportable, S-band dual-polarimetric radar systems in the world. It is an impressive facility, now sporting an 8.5 meter parabolic antenna reflector with an attendant heavy-duty pedestal and drive system designed to collect precipitation data in strong winds and heavy icing conditions. It was successfully deployed by GPM to northern Oklahoma in the summer of 2011 as a key measurement system

in the Mid-Latitude Continental Convective Clouds Experiment. The 610.W TOGA C-band radar was also deployed to the Indian Ocean this year aboard a ship to study atmospheric convection and the Madden-Julien Oscillation during its multi-month participation in the DYNAMO experiment. ***(John Gerlach)***

The Airborne Topographic Mapper flew missions aboard the DC-8 over Antarctica during the fall in support of Operation Ice Bridge. During its mission, the ATM provided a unique observation of a large fracture initiating along the Pine Island Glacier. ***(William Krabill)***

The resident 610.W Air Sea Interaction Facility (ASIF) was used in two projects. The first project studied the heat flux transfer across the ocean-atmosphere interface, in collaboration with Western Connecticut State University (J. Boyle). The second experiment examined the effect of wave surface statistics on optical glint off the wave surface, a collaborative effort with Stevens Institute of Technology (K. Stamnes and grad students). The research conducted this year by the ASIF supported dissertation work for several doctoral students and also resulted in a book chapter and a peer-reviewed journal article. ***(Steven Long)***

The resident 610.W Rain-Sea Interaction Facility (RSIF) deployed the Precipitation Video Imager in two field projects to support the NASA GPM Ground Validation program. The Finnish Meteorological Institute (FMI) was provided with PVI measurements during the 2010 winter extension of the CloudSat/GPM Light Precipitation Validation Experiment (LPVEx), which was a project to evaluate and improve satellite precipitation estimates at high latitudes. In situ and remote measurements of liquid and frozen precipitation from the ground and satellites were collected in the vicinity of Helsinki, Finland (contact walt.petersen@nasa.gov). RSIF also provided PVI measurements in advance of the GPM Cold Season Precipitation Experiment (GPCEX) during the winter of 2011. GPCEX is a collaborative effort between NASA GPM and Environment Canada designed to study the physical characteristics of falling snow in support of the development and testing of GPM core and constellation satellite falling-snow retrieval algorithms. ***(Larry Bliven, Walt Petersen, Gail Jackson, and David Hudak)***

CY2011 was also a busy year for the Wallops Field Support Office's meteorological sounding program. The Sounding Facility participated in the upcoming Low Density Sonic Decelerator program (LDSD). LDSD is a JPL program managed by the Wallops Flight Facility. The Office is providing surplus meteorological rocketsondes, software, and analysis expertise to enable the LDSD project to recover profiles of density and wind information during deployment of the LDSD payload. LDSD payload launch and deployment is currently planned to occur over Hawaii in 2013. The Sounding Facility also successfully completed another year of ozone measurements from Wallops Island. Instrumentation projects included balloon-borne ozonesondes for vertical profiles, the Dobson Spectrophotometer, and the Global UltraViolet (GUV) photometer for total ozone overburden. The Wallops Field Support Office is also the point of contact with INPE in Brazil for cooperatively obtaining ozonesonde measurements for the SHADOZ network. ***(Frank Schmidlin)***

3. MAJOR ACTIVITIES

3.1. Missions

Science plays a key role in the Earth Science Atmospheric Research Laboratories, which involves the interplay between science and engineering that leads to new opportunities for research through flight missions. Atmospheric research scientists actively participate in the formulation, planning, and execution of flight missions and related calibration and validation experiments. This includes the support rendered by a cadre of Project Scientists who are among the most active and experienced scientists in NASA. The following sections summarize mission support activities that play a significant role in defining and maintaining the broad and vigorous programs in Earth Science. As shown, the impact of atmospheric sciences on NASA missions is profound.

3.1.1. Decadal Study Missions

3.1.1.1 ACE

The Aerosols, Clouds, and Ecology (ACE) mission provides major new measurement capabilities to: 1) Enable dramatic steps forward in understanding the direct radiative role of aerosols in global climate change, and the indirect aerosol effects via interactions with clouds, precipitation, and cloud processes; and 2) Observe key properties of marine ecosystems and ocean carbon pools not presently available from existing sensors.

In order to further refine the mission science objectives and requirements, thirteen science definition-related studies were supported in FY2011, including an ACE Ocean Productivity and Carbon Cycle Workshop and ACE ocean lidar performance assessment study. To reduce instrument development risk, six additional studies were supported in FY2011, including two focused on polarimeters, two on lidar, and two on radar. At Goddard, the development of the PACS airborne polarimeter continued and data was collected. Refurbishment of Cloud Radar System (CRS, w-band) was initiated. Assessment of potentially complementary international science missions and their contributions to mission deliverables was continued, which built upon the mission architecture studies completed in 2010, i.e., single versus multiple platforms, orbit optimization, formation flying, and instrument operations/co-alignment requirements. The development of draft ACE Mission STMs also continued, with buildable instrument concept descriptions and mission implementation description. Completion is anticipated in FY2012. Polarimeter Science Assessment Flights are planned in spring 2012 (three polarimeter instruments, eMAS, and CPL from ER-2) to support maturation of algorithms and trade studies as regards instrument concepts. For further information, please contact David Starr (david.starr@nasa.gov).

3.1.1.2 GEO-CAPE

Geostationary Coastal and Air Pollution Events (GEO-CAPE) is one of the missions recommended by the National Research Council's Decadal Survey. This mission is to deploy a geostationary satellite over the continental United States, which would carry out measurements of tropospheric pollutants (O_3, NO_2, SO_2, aerosols) and ocean color in coastal areas with high spatial and temporal resolution. Such resolution would allow fine mapping of pollution emission and events, which would provide a better understanding of the processes involved in pollution transformation and transport. The mission is a Tier-2 mission, with expected deployment after 2020. Recent mission science and cost assessment suggest that the mission could be best achieved by separating the ocean color and atmospheric instruments, and looking for windows of opportunity to deploy some instruments in platforms already planned.

Highlights of the work carried out by Code 614 include:

The planning for GEO-CAPE continued in 2011 with the examination of spatial and temporal variability over the northeastern United States using simulated trace gas and aerosol fields generated by a regional chemical model, WRF-Chem, at 4-km horizontal resolution. Spatial and temporal gradients were compared according to the precision requirements specified in the current GEO-CAPE Science Traceability Matrix. On average, 25 to < 50% of the gradients in tropospheric column NO_2 and ~10–20% of the gradients in tropospheric column SO_2 would be detectable at a horizontal resolution of 4 km. For NO_2 and SO_2, temporal resolutions of three and five hours, respectively, are needed to observe 50% of their temporal gradients. Nearly all horizontal and temporal variability in tropospheric column HCHO falls below its current precision requirement, implying that this value should be made more precise.

A new pixel averaging and spatial filtration technique has been developed, which allows quantifying emission trends from SO_2 and NO_2 pollution point sources (e.g., coal power plants, smelters, oil refineries). The technique has been successfully demonstrated to quantify SO_2 pollution from power plants using Aura/OMI UV measurements over the GEO-CAPE domain (i.e., North America). The technique requires averaging about 100 individual satellite measurements ("snap-shots") of a target assuming that the true emission source does not change. With GEO-CAPE, about a week is required to collect measurements, allowing the study seasonality of the emissions. The best use of the technique will be the use of proposed zoom measurements from GEO-CAPE. In zoom mode, GEO-CAPE will take more frequent measurements over smaller region (e.g., Eastern US) under good weather conditions (i.e., fewer clouds). During zoom operations, the sample of 100 snap-shots can be achieved within one day.

Aerosol retrieval characteristics at different instrument pixel resolutions were investigated, using the standard MODIS aerosol cloud mask applied to MODIS data and a new GOES-R cloud mask applied to GOES data, for a domain covering North America and surrounding oceans. The analysis suggests that sensor resolutions of between 1×1 km or 2×2 km are required to retrieve aerosols in the partly cloudy scenes and to characterize daytime aerosol variations from a geostationary satellite.

John Moisan (610.W) developed a hyperspectral inverse model for retrieving ~18 phytoplankton pigments using satellite remote sensing. The model characterizes the variability of ocean color within the spatial resolution of GEO-CAPE's 250 m × 250 m pixels. In conjunction with this work Moisan also developed the Hyperspectral Ocean Phytoplankton Exploration (HOPE) sensor, a low cost, fiber optic-based, remote-sensing reflectance instrument for small ocean platforms. For further information, please contact Jose Rodriguez (jose.rodriguez@nasa.gov).

3.1.1.3 ASCENDS

The Active Sensing of CO_2 Emissions over Nights, Days, and Seasons (ASCENDS) mission, recommended by the NRC's 2007 Earth Science Decadal Survey, is considered the technological next step following deployment of passive instruments such as the Japanese Greenhouse gases Observing Satellite (GOSAT, 2009) and the NASA Orbiting Carbon Observatory re-flight (OCO–2, expected in 2013). Using an active laser measurement technique, ASCENDS will extend CO_2 remote-sensing capability to include uninterrupted coverage of high-latitude regions and nighttime observations with sensitivity in the lower atmosphere. The data from this mission enable investigations of the climate-sensitive southern ocean and permafrost regions, produce insight into the diurnal cycle and plant respiration processes, and provide useful new constraints to global carbon cycle models. NASA currently plans for launch in 2019–2021.

The Atmospheric Chemistry and Dynamics Laboratory supports ASCENDS through technology development, analysis of airborne simulator data, instrument definition studies, and carbon cycle modeling and analysis. Bill Heaps (614) is Principal Investigator for an Instrument Incubator Program (IIP) project to develop a broadband laser system with Fabry-Perot detection that may be a candidate for the ASCENDS instrument. Lab members also participate on technology projects, led by the Laser Remote Sensing Branch, which target instrument and mission development for ASCENDS. They play a key role in radiative transfer modeling, retrieval algorithm development, instrument field deployment, and data analysis on a project to develop a laser spectrometric instrument for ASCENDS. Based on experience and knowledge of carbon cycle science, they actively help to keep the technology development on track to best achieve the science objectives for ASCENDS. They also support the ASCENDS flight project by performing observing system simulations to establish science measurement requirements and to evaluate the impact of various mission technology options. For further information please contact S. Randolph Kawa (stephan.r.kawa@nasa.gov). ASCENDS workshop Web site: http://cce.nasa.gov/ascends/index.htm.

3.1.1.4 Global 3D-Winds

The NRC Decadal Survey for Earth Science has identified the Global Tropospheric 3D-Winds mission as one of the 15 priority missions recommended for NASA's Earth Science program. The 3D-Winds mission will use Doppler lidar technology to accurately measure the global tropospheric wind field (0 to 20 km altitude) in order to fill this important gap in the global observing system. The Decadal Survey panel recommended a two-phase approach to achieving an operational global wind measurement capability. For the first phase, the panel recommended that NASA develop and fly a pre-operational mission to demonstrate the technology and measurement concept and establish the performance standards for an operational wind mission. The second phase would develop and fly an operational, satellite-based wind system based on this technology. In FY2011, we made significant advances in the technology readiness of the direct detection Doppler lidar approach. Highlights include the February 2011 test flights of the TWiLiTE Doppler lidar system from NASA's high altitude ER-2 research. These flights yielded the first measured profiles of winds through the entire troposphere. These wind profiles, which extend from the aircraft altitude of 20 km to the surface with a vertical resolution of 250 m, demonstrate the data utility of the Doppler lidar wind system. Further ER-2 flights of TWiLiTE are planned in FY2012, after which the instrument will be reconfigured to fly on the NASA Global Hawk as part of the Hurricane and Severe Storm Sentinel (HS3) Earth Venture Mission. We also continued to explore new technologies in collaboration with the Engineering Directorate by developing a new Hybrid Wind Lidar Transceiver (HWLT) telescope system. The HWLT utilizes a unique, all-composite structure that greatly reduces the weight, increases the stiffness, and decreases temperature sensitivity of the telescope system. Finally a space-based Mission study, jointly sponsored by NASA, NOAA, and the Air Force, was carried out in the Goddard Integrated Design Center to explore the possibility of flying a Doppler lidar system on the ISS in the next several years. For further information, please contact Bruce Gentry (bruce.m.gentry@nasa.gov).

The decadal missions described above were led and coordinated by study scientists in the various laboratories as listed in Table 3.1. These people are among the most experienced and active scientists in the laboratories. They advocate for the missions, formulate mission design goals, define measurement and instrument requirements consistent with scientific requirements; perform modeling and simulation studies; plan field measurement and validation activities; serve as liaison with engineering designers and headquarters managers; and assure that system elements, data processing, operating procedures, and cost are compatible with mission requirements and guidelines.

Table 3.1: Mission Study Scientists

Name	Mission
David Starr	ACE
Jose Rodriguez/John Moisan	GEO-Cape
Randy Kawa	ASCENDS
Bruce Gentry	Global 3D-Winds

3.1.2. NASA Planned Missions

3.1.2.1 GPM

The Global Precipitation Measurement (GPM) is an international satellite mission to provide next-generation observations of rain and snow worldwide every three hours. NASA and the Japanese Aerospace Exploration Agency (JAXA) will launch a "Core" satellite in 2014 carrying advanced instruments that will set a new standard for precipitation measurements from space. The data they provide will be used to unify precipitation measurements made by an international network of partner satellites to quantify when, where, and how much it rains or snows around the world. The GPM mission will advance our understanding of the water and energy cycles, and extend the use of precipitation data to directly benefit society.

In partnership with the Department of Energy Atmospheric System Research (ASR) Program, GPM conducted the Midlatitude Continental Convective Clouds Experiment (MC3E) field campaign in central Oklahoma from April 22 to June 6 to support the testing and validation of remote-sensing capabilities of GPM Core sensors (see Section 4.1). For data and more information on MC3E, visit: http://gpm.nsstc.nasa.gov/mc3e/.

GPM launched a new integrated Science and Flight Project website for GPM and TRMM at http://gpm.nasa.gov (also known as http://pmm.nasa.gov). The website provides the latest news and information about the science and engineering status of NASA's GPM and TRMM missions. Visitors can learn about how these missions measure precipitation measurement from space and how we can use this information to explore topics of extreme weather, rain and snow characteristics, societal applications, and satellite engineering. This website also provides portals to all available data products from the mission and field campaigns. GPM also started a Facebook page and began twittering in 2011.

For further information about the GPM Mission, please visit the GPM homepage at http://gpm.nasa.gov, or contact Arthur Y. Hou (arthur.y.hou@nasa.gov).

3.1.2.2 LDCM

The Landsat Data Continuity Mission (LDCM) will be the eighth satellite in the Landsat series that began with the launch of Landsat 1 in 1972 and it is the successor mission to Landsat 7 launched in 1999. The LDCM is being developed and will be operated through an interagency partnership between the NASA and the United States Geological Survey (USGS) within the Department of Interior. NASA leads the building and launching of the satellite observatory with two Earth-observing sensors and the Goddard Space Flight Center is implementing it for NASA. USGS leads the development of the ground system and will lead satellite operations including collecting, archiving, and distributing LDCM data. The USGS intends to rename the satellite observatory "Landsat 8" following launch. The primary objective of the LDCM is to continue and improve upon the now 40-year record of global land observations from space for studies of land cover and land use change over time.

A great deal of progress was made in 2011 with the LDCM observatory moving into the integration and test phase. The Orbital Sciences Corporation assembled the spacecraft bus under contract to NASA at facilities in Gilbert, Arizona and prepared the spacecraft for payload integration. Ball Aerospace and Technology Corporation built one sensor, the Operational Land Imager (OLI), under contract to NASA and shipped OLI to Gilbert in October 2011. Goddard completed the other instrument, the Thermal Infrared Sensor (TIRS), and shipped it to Gilbert in February 2012. The integrated observatory will be subject to comprehensive performance and environmental testing before sending it to Vandenberg Air Force Base in California, scheduled for September 2012, for integration onto the launch vehicle and launch. NASA selected the United Launch Alliance Atlas V 401 as the LDCM launch vehicle. The window for launch is January 15 to February 15, 2013.

James Irons, the Associate Deputy Director for Atmospheres in the Earth Sciences Division, also serves as the LDCM Project Scientist. He has oversight of all aspects of LDCM implementation and operation in order to ensure the scientific integrity of the mission. He also co-chairs the USGS-sponsored Landsat Science Team at the invitation of USGS. After six years of mission formulation followed by the last five years of development, the early 2013 LDCM launch is a much anticipated event. For further information, please contact James Irons (james.r.irons@nasa.gov).

3.1.2.3 JPSS

As background, the National Polar Orbiting Environmental Satellite System (NPOESS) was a tri-agency program between NASA and the Department of Commerce (specifically the National Oceanic and Atmospheric Administration, or NOAA), and the Department of Defense (DoD, specifically the Air Force). It was designed to merge the civil and defense weather satellite programs in order to reduce costs and provide global weather and climate coverage with improved capabilities above the current system. The President's FY2011 budget contained a major restructuring of the NPOESS Program. Under the restructured system, NASA and NOAA will take primary responsibility for the afternoon orbit, and DoD will take primary responsibility for the early morning orbit. The agencies will continue to partner in those areas that have been successful in the past, such as a shared ground system.

The NASA/NOAA portion was notionally named the "Joint Polar Satellite System" (JPSS). The satellite system is a national priority—essential to meet both civil and military weather-forecasting, storm-tracking, and climate-monitoring requirements. In 2011, the JPSS program focused its near-term efforts on supporting the launch of Suomi NPP. The JPSS program will provide three of the five instruments, the ground system, and post-launch satellite operations to the NPP mission. The future JPSS missions, J1 and J2, are currently scheduled for November 2016 and November 2021 launches. The J1 mission will be very similar to NPP, using the same spacecraft and instrument complement. A program concept review was held in the spring of 2011 to be followed by the JPSS System Requirements Review in early summer 2012. For further information, please contact James Gleason (james.gleason@nasa.gov).

JPSS will carry CrIS and ATMS, which are advanced infra-red and microwave atmospheric sounders that designed as follow-ons to the AIRS and AMSU instruments flying on EOS Aqua. Scientists at Goddard are conducting research to optimize products derived from CrIS/ATMS observations using a scientific approach analogous to that used by the AIRS Science Team. The quality and spatial coverage of GSFC CrIS/ATMS sounding products will be compared to those of NOAA-derived CrIS/ATMS products, as well as to AIRS/AMSU products. The main objective of this work, from the NASA perspective, is to assess whether CrIS/ATMS is an adequate replacement for AIRS/AMSU beyond its expected lifetime through 2020, or if improved instruments should be developed for flight on J2. For further information, please contact Joel Susskind (joel.susskind-1@nasa.gov).

3.1.2.4 JPSS Free Flyer (TSIS)

NASA, as part of the JPSS partnership with NOAA, is working to fly the Total and Spectral Solar Irradiance Sensors (TSIS) on the Free Flyer Mission. Free Flyer will also carry the climate sensors package. The TSIS sensor package's build has completed at University of Colorado, and will be tested during 2012. TSIS consists of 2 sensors—a new Total Irradiance Monitor (TIM) and a new Spectral Irradiance Monitor (SIM) instruments, both continuing the heritage TIM and SIM currently flying onboard SORCE. The new TIM and SIM will each be fully traceable to the respective cryogenic radiometer facilities located at University of Colorado's Laboratory for Atmospheric and Space Physics (LASP.) These facilities are unique in the world, providing direct comparison in vacuum to cryogenic radiometers, using optical sources with power comparable to the Sun. The full characterization and traceability has been critical for meeting the required absolute accuracy. Equally important is the exacting degree of stability and precision met by these instruments, critical for any possible future direct determination of a decadal or longer trend in the Sun's variability. This will determine whether the Sun may be enhancing or reducing global warming that would otherwise occur if changes in atmospheric composition, due to greenhouse gases, volcanic or other aerosol emissions, or to natural atmosphere-ocean variations, were the only forcing mechanisms. Since the Sun's changing irradiance is the only well-established, external mechanism forcing the Earth's climate, it is critical to determine its sign and magnitude. For further information, please contact Robert Cahalan (robert.f.cahalan@nasa.gov).

3.1.2.5 DSCOVR

In 2011, Goddard's Atmospheric Research scientists were involved in the refurbishment of the two instruments on board the Deep Space Climate Observatory (DSCOVR) spacecraft. These instruments are National Institute of Standards (NIST) Advanced Radiometer (NISTAR), and Earth Polychromatic Imaging Camera (EPIC). The four-channel radiometer NISTAR provides measurements to improve estimates of the Earth's radiation budget, while the 10-channel telescope-spectroradiometer EPIC measures global ozone levels, aerosol index, aerosol optical depth, scene reflectivity, cloud height, vegetation, and leaf area indices. As part of the refurbishment program, NISTAR and EPIC were recalibrated, stray light for EPIC was corrected, and cloud height measurements were improved by replacing the older channels with the new oxygen-A and -B bands channels. After refurbishment, the instruments were returned to GSFC and integrated with the spacecraft. Algorithms development, ground systems, data reception and transmission are awaiting future direction from NASA. For further information, please contact Alexander Marshak (alexander.marshak@nasa.gov) or Jay Herman (jay.r.herman@nasa.gov).

3.1.2.6 ICESat II

John Moisan (610.W) completed development of a method to retrieve directional spectra from cross-track observations along the satellite's flight path with improvements and modifications aimed at photon counting technology in development for the ICESat-II mission. He is presently testing this algorithm using observations from the recent MABEL flights over the Pacific ocean. For further information, please contact John Moisan (john.r.moisan@nasa.gov).

3.1.3. NASA Active Flight Missions

3.1.3.1 Terra

Launched on December 18, 1999 as NASA's Earth Observing System flagship observatory, Terra carries a suite of five complementary instruments: 1) ASTER (contributed by the Japanese Ministry of Economy, Trade and Industry with a U.S. science team leader at JPL) provides a unique benefit to Terra's mission

as a stereoscopic and high-resolution instrument used to measure and verify processes at fine spatial scales; 2) CERES (LaRC) investigates the critical role that clouds, aerosols, water vapor, and surface properties play in modulating the radiative energy flow within the Earth-atmosphere system; 3) MISR (JPL) characterizes physical structure from microscopic scales (aerosol particle sizes and shapes) to the landscape (ice and vegetation roughness, and texture) to the mesoscale (cloud and plume heights and 3D morphologies); 4) MODIS (GSFC) acquires daily, global, and comprehensive measurements of a broad spectrum of atmospheric, ocean, and land properties that improves and supplements heritage measurements needed for processes and climate change studies; and, 5) MOPITT (sponsored by the Canadian Space Agency with an NCAR science team) retrieves carbon monoxide total column amounts as well as mixing ratios for ten pressure levels; its gas correlation approach still produces the best data for studies of horizontal and vertical transport of this important trace gas.

For more than 12 years, the Terra mission has been providing the worldwide scientific community with an unprecedented number of high-quality quantitative datasets making a significant contribution to all of NASA's Earth Science focus areas. The year 2011 made the record books as a year of historic extreme events, including volcanic activity, earthquake, tsunami/flooding, hurricane/tornado, drought/heat wave, and wildfire. After 12 years of continuous operation and more than 7000 refereed publications (and numerous conference presentations and press releases) using Terra products, we at the project office coordinate closely with the science and engineering team and advocate for the EOS science to maintain a strong Terra program. For further information, please contact Si-Chee Tsay (si-chee.tsay-1@nasa.gov).

3.1.3.2 Aqua

The Aqua spacecraft, launched on May 4, 2002, carries six Earth-observing instruments: AIRS, AMSU, AMSR-E (currently non-operational), CERES (two copies), HSB (no longer operating), and MODIS (also flying on Terra). In the report of the 2011 Senior Review panel (available at http://nasascience.nasa.gov/earth-science/missions/operating/), Aqua received the highest score for scientific merit, scientific relevance, and scientific product maturity; and was one of three missions to receive the highest ranking for utility. Aqua's overall score from the National Interests Panel was the highest of all current NASA missions, and it was the only mission rated as "Very High Utility" by every agency doing the rankings.

In addition to collecting data regarding Earth's water as highlighted in the name "Aqua," mission instruments also provide radiative energy flux, atmospheric temperature and composition, dust and aerosols, cloud properties, land vegetation, phytoplankton and dissolved organic matter data from the oceans, surface albedo, temperature, and emissivity. These measurements help scientists to quantify the state of the Earth system, validate climate models, address key science questions, and serve the applications community.

Aqua Deputy Project Scientist, Lazaros Oreopoulos supports the mission as an advocate (organizing the "Aqua at 10" Union Session at the Fall 2011 AGU meeting, among other activities) and leads budgetary matters and contracts. For further information, please contact Lazaros Oreopoulos (lazaros.oraiopoulos-1@nasa.gov).

The Goddard DISC has generated and distributed scientific products derived from AIRS/AMSU observations for the period September 2002 through March 2012 using the AIRS Science Team Version-5 retrieval algorithm. There have been numerous scientific publications describing the use of AIRS Version-5 products to aid in the monitoring and understanding of climate processes as well as to improve the ability to predict the location and intensity of storm tracks. More information about AIRS and related research can be found at airs.jpl@nasa.gov. Joel Susskind (610AT) is a member of the AIRS Science Team and has been instrumental in the development and validation of the AIRS Science Team Version-5 retrieval algorithm as well as the AIRS Version-6 Science Team retrieval algorithm, which is expected to become operational at the Goddard DISC in the summer of 2012. For further information, please contact Joel Susskind (joel.susskind-1@nasa.gov).

3.1.3.3 Aura

The Aura spacecraft, which was launched July 15, 2004, carries four instruments to study the composition of the Earth atmosphere. The Ozone Monitoring Instrument (OMI), the Microwave Limb Sounder (MLS), the High Resolution Dynamics Limb Sounder (HIRDLS), and the Tropospheric Emission Spectrometer (TES) make measurements of ozone and constituents related to ozone in the stratosphere and troposphere, aerosols, and clouds. With these measurements the science team addresses questions concerning the stratospheric ozone layer, air quality, and climate. It has now been more than seven years since launch, and two of the instruments continue to make daily measurements. HIRDLS suffered an anomaly and is no longer operational. TES shows signs of aging and presently makes limited measurements.

In 2011 Aura data revealed new aspects of the Earth composition while it continues to build a multi-year, global dataset that will show connections between chemistry and climate. Spring 2011 was one of the coldest on record, and although manmade chlorine levels in the stratosphere have begun to decline, OMI total ozone measurements and MLS measurements related to stratospheric chemistry are being used to explain the causes of some of the lowest recorded ozone levels in the northern polar vortex. OMI measurements of sulfur dioxide confirm major reductions in the pollution from power plants in the eastern United States. Information derived from TES measurements taken over several years provides unique information about the rainfall, evaporation, and mixing, which are being used to evaluate moisture processes in climate models. HIRDLS high vertical-resolution profiles have revealed details of the structures of equatorial waves and gravity waves in the stratosphere. More information on the Aura science highlights can be found at http://aura.gsfc.nasa.gov/ or contact Anne Douglass (anne.r.douglass@nasa.gov).

3.1.3.4 GOES

NOAA's Geostationary Operational Environmental Satellites (GOES) satellites are built, launched, and initialized by Goddard's GOES Project Office under an inter-agency program. The GOES series of satellites carry sensors that continuously monitor the Earth's atmosphere for developing weather events, the magnetosphere for space weather events, and the Sun for energetic outbursts. The project scientist assures the scientific integrity of the GOES sensors throughout the mission definition, design, development, testing, operations, and data analysis phases of each decade-long satellite series. In 2011, construction began on five new and improved instruments for the next generation of GOES satellites. The project scientist also operates a popular GOES ground station that offers real-time, full-resolution, calibrated GOES images to support scientific field experiments and to supply Internet users with high-quality data during severe weather events.

The GOES Project Science Web site (http://goes.gsfc.nasa.gov/) displays real-time GOES imagery and provides high-quality data to the scientific community. For example, in a non-hurricane month (May 2006), the site served 50 GB/day to 46 thousand distinct hosts at the average rate of 2 requests per second. During a hurricane, the Web server typically hits its limit of 10 requests per second to 150 simultaneous guests. For further information, please contact Dennis Chesters (dennis.f.chesters@nasa.gov).

3.1.3.5 SORCE

Since its launch in January 2003, the Solar Radiation and Climate Experiment (SORCE) has achieved its goal of simultaneously measuring total solar irradiance (TSI) and solar spectral irradiance (SSI) in the 0.1–27 nm and 115–2400 nm wavelength ranges with unprecedented accuracy and precision. SORCE has successfully completed its five-year core mission (January 2003 to January 2008) and is now in the fifth year of its extended mission. SORCE has acquired new and unique observations of the solar irradiance and has improved understanding of solar radiative forcing of Earth's climate and atmosphere during the descending phase of solar activity cycle 23 and now into the rising phase of solar cycle 24.

NASA's SORCE mission will complete nine years in orbit on January 25, 2012. The year 2011 was a banner year for the Total Irradiance Monitor (TIM), with publication of A new lower value of total solar irradiance by G. Kopp and J. Lean (*Geophysical Research Letters*, L01706, vol. 38, 2011; doi:10.1029/2010GL045777) that calculated a value of 1360.8 ± 0.5 W/m^2 during the minimum of solar cycle 23. After this publication appeared, two other TSI instruments currently in orbit–NASA's ACRIM 3 onboard Acrimsat, and Premos onboard ESA's Picard mission–each announced that they were applying a new bias correction that now brings each of them down by more than 4 W/m^2 to align them with TIM's lower value, which leaves only the ESA Virgo showing continual disagreement with TIM. This new precise agreement between the three instruments was primarily enabled by the cryogenic Transfer Radiometer Facility at University of Colorado LASP, a development supported by the SORCE mission. SORCE, at nine years old and counting, is now well beyond its five year design life; its batteries are showing the inevitable signs of aging, with several cells now not functional. The follow-on mission, the Total and Spectral Solar Irradiance Sensor, or TSIS, is set to fly onboard the JPSS Free-Flyer mission, but due to budget constraints the launch of Free-Flyer is not expected to come in time to avoid a gap in the 33-year TSI record that SORCE has continued. It is indeed ironic that a gap in the longest space-based climate record is now threatened in the same year that the historic gap between concurrent TSI measurements is successfully being closed. For further information, please contact Robert Cahalan (robert.f.cahalan@nasa.gov).

3.1.3.6 TRMM

The Tropical Rainfall Measuring Mission (TRMM), launched in late 1997, is a joint mission between NASA and JAXA, the Japanese space agency. The first-time use of both active and passive microwave instruments and the processing, low inclination orbit have made TRMM the world's foremost satellite for the study of precipitation and associated storms and climate processes in the tropics. TRMM instruments include the first and only precipitation radar (PR) in space, the TRMM microwave imager (TMI), a visible and infrared scanner (VIRS), and a lightning imaging sensor (LIS). TRMM's original goal was to advance our understanding of the mean distribution of tropical rainfall and its relation to the global water and energy cycles. As the TRMM mission has now continued into its 15th year, the science objectives have extended beyond just determining the mean precipitation distribution and have evolved toward determining the time and space varying characteristics of tropical rainfall, convective systems, and storms and how these characteristics are related to variations in the global water and energy cycles.

In 2011, the TRMM mission successfully completed the Senior Review Process, a biennial review of the status and achievements of the mission, and received approval for mission continuation through at least 2013. TRMM fuel levels are sufficient for continued operations until at least mid-2013 and as late as early 2015. The TRMM mission also implemented Version 7 of the rainfall retrieval algorithms. The biggest advance was in the algorithm for the TMI, which replaced its core database of numerical-model-derived hydrometeor profiles with precipitation profiles derived from the Precipitation Radar. In addition, the algorithm subsets scenes by sea-surface temperature and total precipitable water to improve detection of regional differences in rainfall. Reprocessing of the entire TRMM rainfall record began July 1, 2011 and was completed by mid-August 2011. Latent heating and multi-satellite products are expected to be completed in early 2012.

The TRMM Web site (http://trmm.gsfc.nasa.gov/) provides near-real-time precipitation estimates every three hours (with daily and weekly accumulations) as well as flood potential maps. A brief synopsis of virtually every major hurricane, typhoon, and flood event around the globe with attendant maps of accumulated precipitation can be found at http://trmm.gsfc.nasa.gov/publications_dir/extreme_events.html/. For further information, please contact Scott Braun (scott.a.braun@nasa.gov).

3.1.3.7 Suomi NPP

The Suomi National Polar-orbiting Partnership (NPP) satellite was launched on October 28, 2011. NPP's advanced visible, infrared, and microwave imagers and sounders are designed to improve the accuracy of climate observations and enhance weather forecasting capabilities for the nation's civil and military users of satellite data. NPP instruments include the Advanced Technology Microwave Sounder (ATMS), the Cross-track Infrared Sounder (CrIS), the Ozone Mapping and Profiler Suite (OMPS), the Cloud and Earth Radiant Energy System (CERES), and the Visible Infrared Imaging Radiometer Suite (VIIRS). The NPP satellite was placed in a Sun-synchronous orbit, a unique path that takes the satellite over the equator at the same local (ground) time in every orbit. So when NPP flies over Kenya, it is about 1:30 p.m. on the ground. When NPP reaches Gabon—about 3,000 kilometers to the west—on the next orbit, it is close to 1:30 p.m. on the ground. This orbit allows the satellite to maintain the same angle between the Earth and the Sun so that all images have similar lighting. Following the successful launch in October, ATMS was the first instrument activated on November 8, 2011 and is already generating scientific data for snow and rain studies. VIIRS also opened its door on November 21, 2011 and started to beam down real-time measurements from its visible and near-infrared channels to the Svalbard ground receiving station. The resulting, first daily, true-color image reveals amazing high-resolution details and complete coverage of the Earth with no orbital gaps at the equator. The routine operation of all five sensors onboard Suomi NPP is scheduled to begin in early March 2012. Figure 3.1 shows early imagery from the ATMS instrument. For further information, please contact James Gleason (james.f.gleason@nasa.gov).

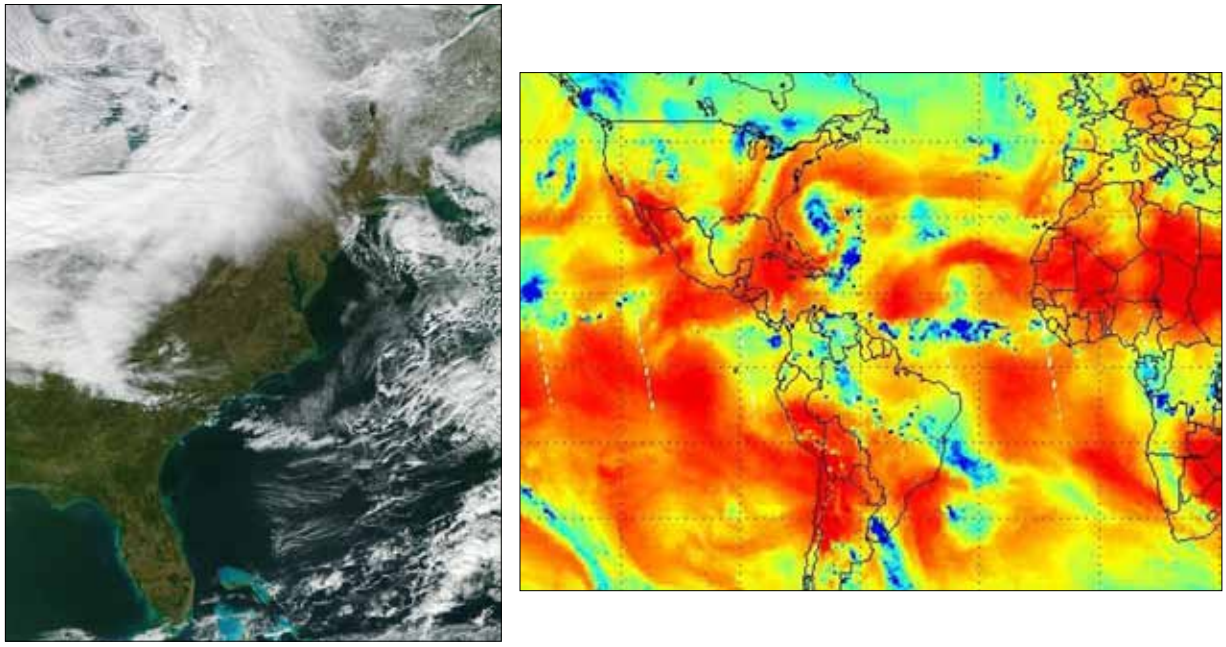

Figure 3.1: This global image shows the ATMS channel 18-microwave antenna temperature at 183.3 GHz on November 8, 2011. This channel measures atmospheric water vapor; note that Tropical Storm Sean is visible in the data, as the blue patch, in the Atlantic off the coast of the Southeastern United States.

3.2. Project Scientists

Project Scientists serve as advocates, communicators, and advisors in the liaison between the Project Manager and the community of scientific investigators on each mission. The position is one of the highest operational roles to which a scientist can aspire in NASA. Table 3.2 lists Project and Deputy Project Scientists for current and planned missions. Table 3.3 lists the validation and mission scientists and major participants in field campaigns.

Table 3.2: Atmospheres Project and Deputy Project Scientist

Project Scientists		Deputy Project Scientists	
Name	**Project**	**Name**	**Project**
Charles Jackman	AIM	Lazaros Oreopoulos	Aqua
Anne Douglass	Aura	Warren Wiscombe	ARM
Steve Platnick	EOS	Bryan Duncan	Aura
Dennis Chesters	GOES	Joanna Joiner	Aura
Arthur Hou	GPM	Alex Marshak	DSCOVR
James Gleason	JPSS/NPP	Gail Jackson	GPM
James Irons	LDCM	Christina Hsu	NPP
Joanna Joiner	OMI	Si-Chee Tsay	Terra
Robert Cahalan	SORCE and TSIS		
Scott Braun	TRMM		

Table 3.3: Atmospheres Validation and Mission Scientists & Major Participants and Instruments

Validation Scientists		Field/Aircraft Campaigns	
Name	**Mission**	**Name**	**Campaign**
David Starr	EOS	Kenneth Pickering	DISCOVER-AQ
Ralph Kahn	EOS/MISR	John Gerlach	DYNAMO/CINDY
		Charles Gatebe	ECO-3D
		Walter Petersen Gail Jackson	GCPEx
		Walter Petersen	GPM GV
		Scott Braun	HS3
		Walter Petersen	MC3E
		Judd Welton	MPLNET
		William Krabill	Operation IceBridge
		Judd Welton Si-Chee Tsay	SEAC4RS

3.3. Measurements

Studies of the atmosphere of Earth require a comprehensive set of observations, relying on instruments borne on spacecraft, aircraft, balloons, or those that are ground-based. Our instrument systems 1) provide information leading to basic understanding of atmospheric processes, and 2) serve as calibration references for satellite instrument validation. Many of the research activities involve developing concepts and designs for instrument systems for spaceflight missions, and for balloon-, aircraft-, and ground-based observations. Airborne instruments provide critical in-situ and remote measurements of atmospheric trace gases, aerosol, ozone, and cloud properties. Airborne instruments also serve as stepping-stones in the development of spaceborne instruments, and serve an important role in validating spacecraft instruments. Details concerning the instruments are presented in a separate Laboratory technical publication, the *Instrument Systems Report*, NASA/TP-2011-215875 which is also available on the Atmospheres home page, http://atmospheres.gsfc.nasa.gov/.

3.3.1. Mesoscale Atmospheric Processes Laboratory

Validating GPM radar and radiometer algorithms

The Tropical Rain Measuring Mission (TRMM) has sampled deep convective systems globally at Ku-band for many years. The Global Precipitation Mission (GPM) will carry the first dual-frequency (Ka- and Ku-band) radar. The High-Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) was recently adapted from its usual location on the Global Hawk to a nadir-pointing configuration on the high-altitude (20 km) ER-2 during the Mid-latitude Continental Convective Clouds Experiment (MC3E). HIWRAP-ER2 along with other ER-2 microwave radiometers will help validate the GPM radar and radiometer algorithms over land.

Figure 3.2 shows that significant attenuation is observed at both Ka- and Ku-band with the Ka-band attenuation occurring below 12-km altitude suggesting the presence of large hail high in the storm. The hailstorms had significantly larger attenuation and Mie scattering effects than expected. Spaceborne radar profiling

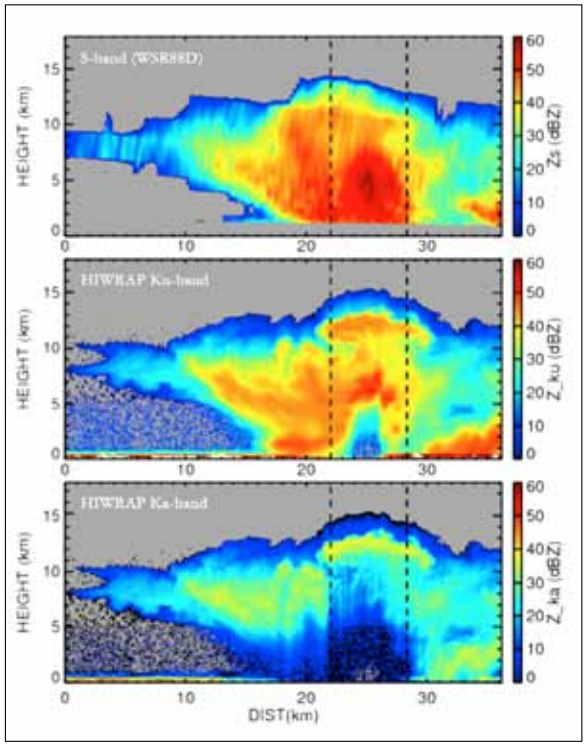

Figure 3.2: Vertical slice through hail storm showing comparison of HIWRAP's ER2 Ka- and Ku-band channels with an S-band, NOAA WSR88D radar.

algorithms will be highly challenging in these large convective systems. The figures demonstrate the first high-altitude, dual-wavelength measurements and the first Ka-band measurements over deep convective storms. For further information, please contact Gerald Heymsfield (gerald.m.heymsfield@nasa.gov).

3.3.2. Climate and Radiation Laboratory

Taking the pulse of Pyrocumulus clouds with field measurements

Forest fires can burn large areas; they can also inject smoke into the upper atmosphere, where stakes are even higher for climate, because these emissions tend to have a longer lifetime and can produce significant regional and even global climate effects, as is the case with some volcanoes. Large forest fires are now believed to be more common in summer, especially in the boreal regions where fire-generated clouds such as pyrocumulus (pyroCu), and occasionally pyrocumulonimbus (pyroCb) clouds are formed, which can transport emissions into the upper atmosphere. A major difficulty in developing realistic fire plume models is the lack of observational data within fire plumes that resolves structure at scales of a few 100 m, which can be used to validate these models.

In this study, we report detailed airborne radiation measurements within strong pyroCu taken over boreal forest fires in Saskatchewan, Canada during the Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS) summer field campaign in 2008. We found a prominent smoke-core inside the pyroCu, which is characterized by very strong absorption of radiation. We derived simple geometrical functions, which are similar to the functions that describe radiation distribution in water clouds. These simple functions have the potential to provide efficient and reasonably accurate solutions of the radiative transfer equation, if some necessary conditions are fulfilled, and allow simulation of radiance characteristics in complicated three dimensional clouds. To gain a better understanding of the pyroCu, we performed Monte Carlo simulations and showed that radiation transport in pyroCu is a very complex phenomenon, which is dominated by both scattering and absorption processes and not yet well understood. (Gatebe et al, "Taking the Pulse 1 of PyroCumulus Clouds" in *IPY Special Issue of Atmospheric Environment*.) For further information, please contact Charles Gatebe (charles.k.gatebe@nasa.gov).

3.3.3. Atmospheric Chemistry and Dynamics Laboratory: Volcanic Measurements

As the primary natural source of sulfur dioxide (SO_2) gas and derived sulfate aerosol in the upper troposphere and lower stratosphere (UTLS), volcanic eruptions also impact climate through direct and indirect aerosol effects. Volcanic ash is a major hazard to jet aircraft at cruising altitudes, and was responsible for significant economic impacts following the eruption of Eyjafjallajökull (Iceland) in April 2010. Forecasting, monitoring, and quantification of volcanic emissions are therefore critical for aviation hazard mitigation and for accurate appraisal of natural climate forcing. Figure 3.3 shows a volcanic cloud from Iceland shortly after overpass on May 23.

Since October 2004, the Ozone Monitoring Instrument (OMI) on NASA Aura produces global daily column SO_2 data archived at Goddard Earth Sciences (GES) Data and Information Services Center (DISC). OMI near-real-time SO_2 images, within three hours of the Aura overpass, can be seen at NOAA Web site: http://satepsanone.nesdis.noaa.gov/pub/OMI/OMISO2/index.html and FMI direct broadcast Web site: http://omivfd.fmi.fi/. Archived daily OMI SO_2 images are available from the public Lab SO_2 Web site: http://so2.gsfc.nasa.gov/. With advances in retrieval techniques, current UV measurements have improved sensitivity to volcanic clouds and provide "top-down" constraints on anthropogenic SO_2 emissions. For further information, please contact Nickolay Krotkov (nickaloy.a.krotkov@nasa.gov).

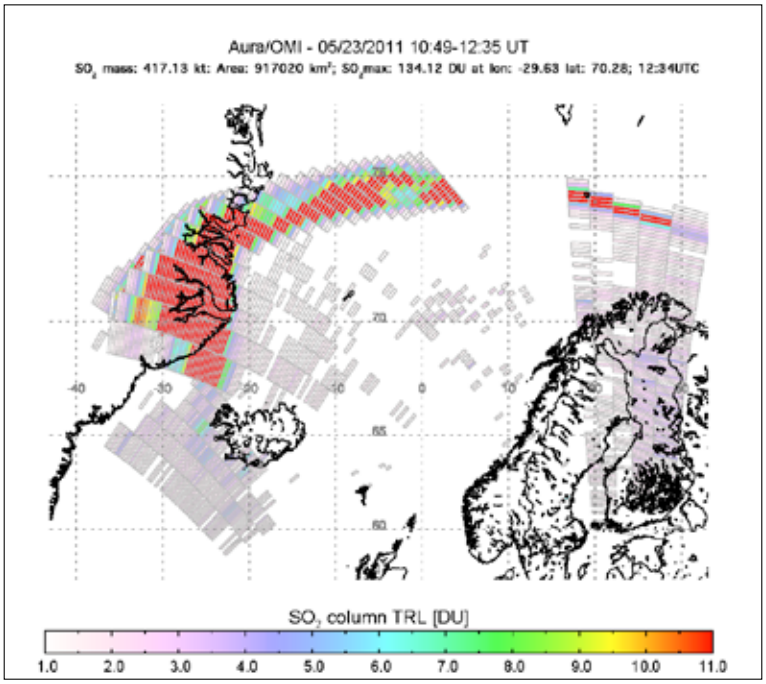

Figure 3.3: OMI SO_2 observations of volcanic cloud from Grimsvotn volcano (on Iceland). The volcano began erupting on May 21 at 1730 UTC. Lasted until May 26th.

3.4. Modeling

Numerical modeling is a critical component of our research, which is highly synergistic to observations from satellite, aircraft remote sensing, and in-situ measurement platforms. Scientist in the ESD-Atmospheres Laboratories are engaged in a variety of modeling studies to simulate and better understand severe weather and high-impact climate phenomena, improve predictions, explore new frontiers of understanding through hypothesis formulation, tested through numerical experiments. Models are also used for observation data assimilation to provide a complete description of state of the atmosphere and for observing system simulations for satellite mission design. Model results will be validated with observations. We use a diverse range of models from global Earth system models, to regional climate models, to cloud resolving models, and 3D radiative transfer models, including representations of physical (aerosol, clouds, and precipitation) and chemical processes (ozone, greenhouse, and trace gases) in the atmosphere and their interaction with the underlying surface. Highlights of our modeling research are described below.

3.4.1. Mesospheric Processes Laboratory/ MMF-LIF

A finite-volume (fv) Multi-scale Modeling Framework (MMF) has been developed at Goddard that combines a finite-volume GCM (Lin 2004) with the Goddard Cumulus Ensemble (GCE) cloud-resolving model (Tao 2003). The fvGCM is run at $2.5° \times 2°$ or $1.25° \times 1°$ horizontal grid spacing with 32 layers from surface to 0.4 hPa. The embedded 2D GCE is run with 64 or 32 horizontal grids and 32 levels with 4-km horizontal grid spacing. This combination provides global coverage with explicit simulation of sub-grid cloud processes and their interaction with radiation and surface processes. The Goddard fvMMF is the second MMF ever developed following a similar effort at CSU (DeMott et al. 2007; Tao et al. 2009).

To improve the representation of cloud-scale moist processes and land-atmosphere interactions, a Land Information System (LIS) was coupled to the fvMMF. The LIS, an advanced land data assimilation system containing multiple land surface models, is described in Kumar et al. (2006). Results from MMF-LIS simulations of 2007–2008 using two versions of the Common Land Model were compared to MERRA and to a series of global gridded observational products. Figure 3.4 is adapted from Mohr et al. (2011), a comprehensive description of the structure and operation of the MMF-LIS. The FLUXNET is a global network of more than 500 micrometeorological tower sites (Baldocchi et al. 2001). Sitting these towers on a wide variety of biomes made it possible to create gridded flux products useful for model validation from local to global scales (Jung et al. 2009; Blyth et al. 2010; Jung et al. 2010; Schlosser and Gao 2010). Compared to the FLUXNET product and to MMF-LIS, the June–August 2007 mean latent heat flux of MERRA is significantly larger over the humid regions of Central Africa, Central to South America, East Asia, Indonesia, and eastern North America. Reichle et al. (2011) attribute this positive bias in areas to excessive interception by dense canopies. The one area of latent heat flux greater than 120 W m^{-2} in the FLUXNET map is in the Central United States. In this region and in arid Australia and Central Asia, the MERRA compares well to the FLUXNET and performs better than both MMF-LIS simulations. In the MMF-LIS modified CLM simulation, changes to several parameterizations, particularly with respect to soil heat transfer, result in better performance over the middle and high northern latitudes compared to the original CLM simulation and to MERRA. For further information, please contact Wei-kuo Tao (wei-kuo.tao-1@nasa.gov).

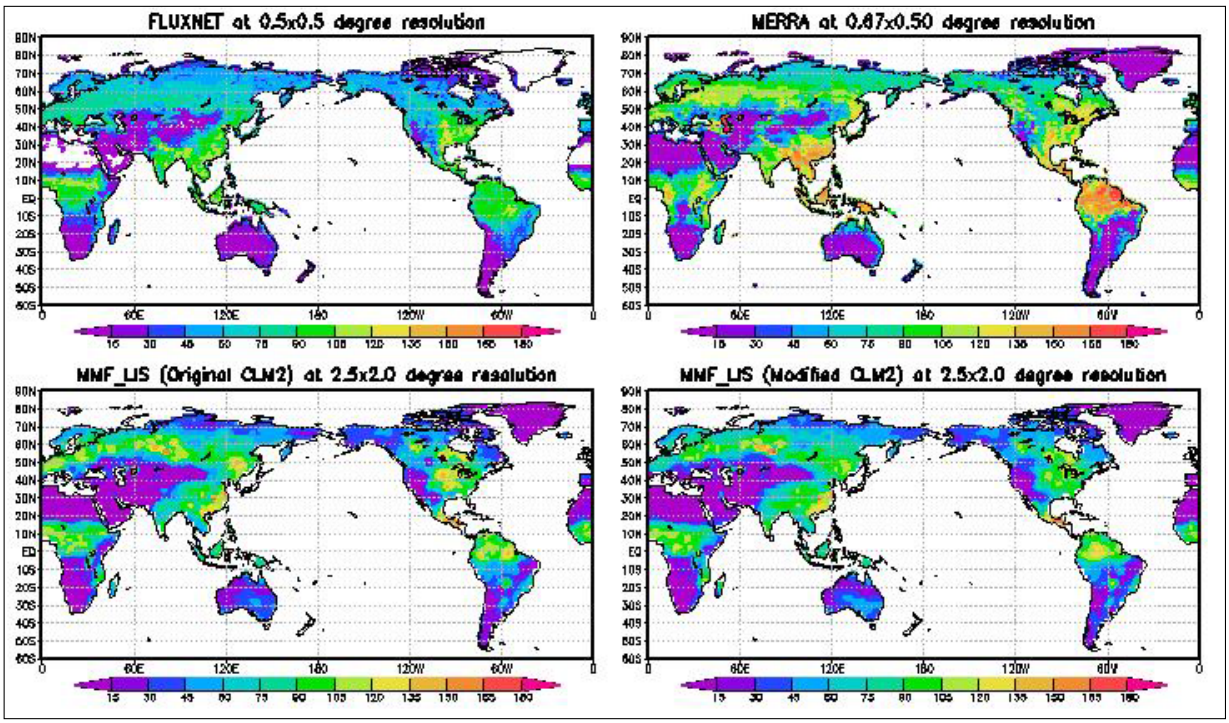

Figure 3.4: Global maps of June–August 2007 mean latent heat flux in W m^{-2} for a) FLUXNET, b) MERRA, c) MMF-LIS using CLM 2.0, d) MMF-LIS using CLM 2.1. The color scale is the same for all maps. Grid resolution of each map is indicated. Figure adapted from Mohr et al. (2011).

3.4.2. Climate and Radiation Laboratory: 3D Radiation Online Calculator

The Intercomparison of 3D Radiation Codes (I3RC) project sponsored the development of a community model of 3D radiative transfer. This model has now been expanded to create the first online calculator of atmospheric 3D radiative processes. The calculator offers researchers, students, and the public a simple way to perform quick simulations to test new hypotheses and to explore 3D radiative processes. For cloud fields specified by users, the calculator can yield the spatial distribution and scene average value of radiances, fluxes, and absorption at selected visible and near-infrared wavelengths. To help better understand the 3D nature of radiative processes, the calculator can also use an approximation widely used in remote sensing and in dynamical models, and perform 1D calculations for each atmospheric column without considering interactions between columns. Since its public release in January 2012, 120 visitors from 21 countries have tried the calculator. The online calculator and the source code of the I3RC community model of 3D radiative transfer are available at http://i3rc.gsfc.nasa.gov/i3rcmodel, or contact Alexander Marshak (alexander.marshak-1@nasa.gov).

3.4.3. Atmospheric Chemistry and Dynamics Laboratory: Coupled Chemistry–Climate Model

The Laboratory for Atmospheric Chemistry and Dynamics has a long and distinguished history in modeling the dynamical and chemical processes that impact stratospheric and tropospheric ozone, and air quality. This effort has been carried out through the use of two-dimensional models for the stratosphere, three-dimensional chemistry-transport models for the stratosphere and troposphere (Global Modeling Initiative, or GMI), and most recently, through the integration of a coupled chemistry–climate model in collaboration with the Global Modeling and Assimilation Office. The latter showed outstanding performance in the inter-model assessment carried out by the Chemistry Climate Model Evaluation (CCMVal) and contributed to the last Ozone Assessment carried out by the World Meteorological Organization.

A major challenge in evaluating chemistry-climate models is testing their response to different forcings in comparison to atmospheric data responding to those forcings. Ziemke et al. (2010) found that the tropospheric ozone column in the tropical Pacific, derived from TOMS and OMI measurements with the cloud slicing method, showed a response to the El Nino Southern Oscillation. Indeed, an "ozone ENSO index" could be defined by looking at the differences in tropospheric ozone between the East and West Pacific. This index correlated extremely well with the traditional ENSO 3.4 index based on sea surface temperature differences.

Oman et al. (2011) carried out a 25-year simulation with the chemistry-climate model, forced by the interannual, observed sea-surface temperatures. Figure 3.5 shows their calculated ozone ENSO index, compared to the "observed" ozone ENSO index and the traditional ENSO 3.4 index. The modeled ozone shows an outstanding agreement with observations. This comparison indicates the excellent model performance to a natural forcing, and constitutes an important test of the model predictability. Ongoing work is analyzing the different chemical and dynamical mechanisms that are responsible for the response to this forcing. For further information, please contact Luke Oman (luke.d.oman@nasa.gov).

References:

Oman, L. D., J. R. Ziemke, A. R. Douglass, D. W. Waugh, C. Lang, J. M. Rodriguez, and J. E. Nielsen The response of tropical ozone to ENSO, *Geophys. Res. Lett.*, 38, L13706, doi:10.1029/2011GL047865, 2011.

Ziemke, J. R., S. Chandra, L. D. Oman, and P. K. Bhartia, 2010: A new ENSO index derived from satellite measurements of column ozone, *Atm. Chem. Phys.*, 10, 3711-3721.

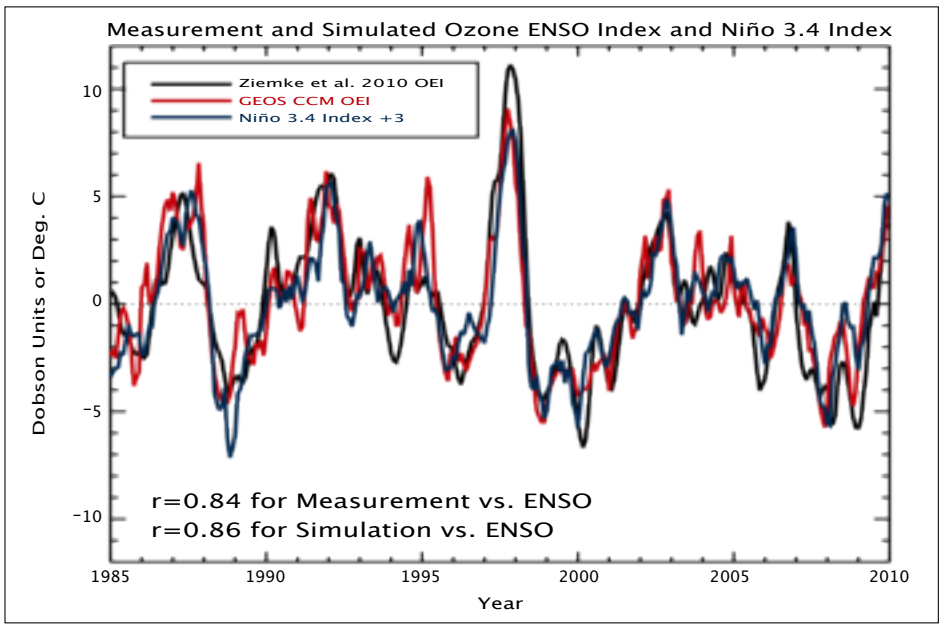

Figure 3.5: Comparison of GEOS CCM simulated (red curve) and a measurement-derived (black curve) ozone ENSO index (OEI) with Niño 3.4 Index (multiplied by 3, blue curve) for the 1985 to 2009 time period.

3.4.4. Wallops Field Support Office—Surface Water Ocean Topography (SWOT)

Chesapeake Bay Sea Level Variability: NASA's Surface Water Ocean Topography (SWOT) mission will be capable of observing coastal sea levels. The present study was carried out to support the mission by providing answers on the spatial and temporal scales of sea-level variability due to various physical forcing processes such as storms, tides, precipitation-evaporation, climate change, and fluvial fluxes. Using models to address these complex questions in a highly complex coastal region is an effective way to obtain answers to various questions that arise during the development of the SWOT mission. A full year (2006) of a sea level height estimates, obtained from a three-dimensional, regional ocean circulation model (regional ocean modeling system or ROMS) of the Chesapeake Bay, was analyzed to determine the altimetric signals from hurricane, tides, and normal estuarine currents. The work was carried out jointly with Jiangtao Xu, a scientist at NOAA/NOS, Brittany Bruder, a summer graduate intern from Georgia Institute of Technology, and Charles Moon, an undergraduate intern. Standard harmonic analysis was applied to hourly simulations of the model's free surface to obtain the amplitude and phase of 39 tidal components at each model grid location within the bay. The "residual" time series was obtained by removing the resulting tidal components (Figure 3.6, left panel). Empirical orthogonal function (EOF) analysis was carried out on these "residuals," and the first EOF accounted for 91.2 percent of the observed variance. The corresponding time series from this first EOF is highly correlated to the NW-SE component of the mean wind field, and demonstrates the influence of the larger scale, longer term impact of winds on retarding or enhancing flow of water through the bay mouth. The second EOF component accounts for 6.6 percent of the variance of the residuals. The time series of this second EOF is correlated with the N-S wind field component. Precipitation, evaporation, and fluvial fluxes have minimal influence on the larger bay's sea level variability, but play a more important role in the upper estuaries.

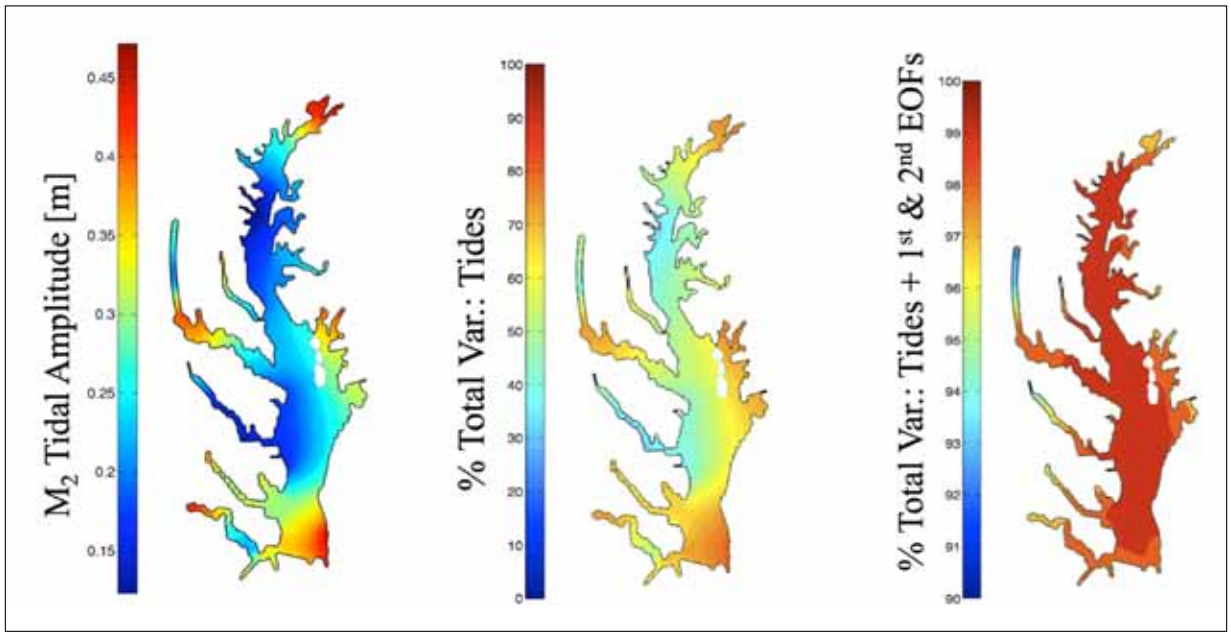

Figure 3.6: The variance in sea level accounted for by the tides, such as the M2 tides (left panel) varies for different regions of the bay (center panel). Taken together, the tidal and wind-driven variance (observed through cross-correlation of the first and second EOFs with the wind field) accounts for about 100% of the variance (right panel) for most areas of the bay.

4. FIELD CAMPAIGNS

Field campaigns use the resources of NASA, other agencies, and other countries to carry out scientific experiments, to validate satellite instruments, or to conduct environmental impact assessments from bases throughout the world. Research aircraft, such as the NASA Global Hawks, ER–2, DC–8, and WB–57F, serve as platforms from which remote sensing and in-situ observations are made. Ground-based systems are also used for soundings, remote sensing, and other radiometric measurements. In 2011, atmospheric research personnel supported activities in the planning and coordination phases as scientific investigators or as mission participants.

4.1. Mid-latitude Continental Convective Cloud Experiment

The Mid-latitude Continental Convective Clouds Experiment (MC3E) sponsored by GPM and in collaboration with DOE involves both the NASA ER-2 with GPM-like instruments, the NASA NPOL and D3R ground radars, the University of North Dakota Citation aircraft for in-situ measurements, and extensive surface measurements for rain. Two ER-2 instruments were provided by Goddard, the HIWRAP radar (G. Heymsfield/612) and the CoSMIR radiometer (G. Jackson/612). HIWRAP provided the first Ka- and Ku-band radar measurements from the ER-2 to simulate the DPR, whereas CoSMIR simulates the higher frequencies of the GMI. David Marks (612) participated as a NPOL radar scientist from April 21 through May 5. Jerry Wang (612) served as NPOL radar scientist.

The campaign began operations with a “bang“ on April 22. The NASA ER-2 carrying one dual-frequency radar and two radiometers initiated data collection over a line of severe thunderstorms in central and northeastern Oklahoma and flew coordinated legs with the Citation aircraft of the University of North Dakota collecting in-situ data in anvil where it was safe for the Citation to fly. The MC3E conducted a second night mission in the early hours of April 25 deploying both the Citation and the ER-2 within range of the NPOL and DOE radars over the DOE Central Facility ground instrument domain. All airborne instruments were operational and the NASA GPM disdrometer network obtained records of large/giant raindrops. Understanding the nature and incidences of these particular drop size distributions will be important for refining GPM sensor algorithms to provide more accurate rainfall estimation over land.

The campaign conducted coordinated ER-2 and UND Citation flights and ground-based measurements for several major MCS. Highlights included a “dream scenario“ over the DOE/ASR South Great Plains (SGP) Central Facility (CF) in Oklahoma on May 20, a complex, severe storm system on May 23 near SGP CF, and the supercell convection that produced tornadoes west and northwest of Oklahoma City on May 24. GPM concluded the campaign with DOE in central Oklahoma on June 6. The experiment sampled a broad variety of precipitation types and intensities—including many cases of severe thunderstorm systems—using two aircraft (NASA/ER-2 and UND/Citation) and an extensive array of ground instruments over a 6-week period. Campaign measurements are being processed and analyzed to directly support GPM algorithm development over land. For further information, please contact Walt Petersen (walt.petersen@nasa.gov).

4.2. Hurricane and Severe Storm Sentinel

Two Global Hawk aircraft will carry out one-month-long missions during the 2012 Atlantic hurricane season. Full science operations with the mission’s suite of seven instruments are scheduled run through 2014. In essence, the Hurricane and Severe Storm Sentinel (HS3) will give scientists something they’ve never had before—a sustained look at storms as they evolve over an extended period of time. To get a complete picture of developing hurricanes, one aircraft will carry four instruments to study environmental

conditions surrounding the storm, including the Cloud Physics Lidar and the Tropospheric Wind Lidar Technology Experiment developed with IRAD funds by Goddard scientists Matt McGill and Bruce Gentry, respectively. NOAA and the University of Wisconsin are providing the other two instruments. The second aircraft will carry Heymsfield's HIWRAP and two other instruments provided by the Marshall Space Flight Center and Jet Propulsion Laboratory. These instruments will measure conditions within the storms from a vantage point directly above the hurricane's vortex.

The investigation completed its 2011 test flights in preparation for deployment in September 2012. HS3 is led by PI Scott Braun (612) and deputy PI Paul Newman (614). HS3 completed integration of all instruments (CPL, S-HIS, and dropsondes) for the environmental aircraft and confirmed instrument functionality with a flight in the Edwards range. After the range flight, CPL was de-integrated and replaced by the HAMSR microwave sounder. Two science flights were conducted to allow intercomparison between temperature and humidity profiles from the two remote sensors (HAMSR and S-HIS) and the in situ measurements from dropsondes. The first science flight was in the Pacific Ocean on September 8th and 9th, with the GH flying to the longitude of Hawaii and moving southward from 50°N to 10°N to create a high-resolution cross section of an atmospheric river (river of high atmospheric moisture). All three instruments performed very well, providing excellent data for the intercomparison. The second science flight was in the Gulf of Mexico on September 13th and 14th, with the goal of doing a coordinated flight with the NOAA G-IV aircraft to compare measurements from the newer GH dropsonde system and the established measurements from the G-IV system. A secondary goal was to test communications between the pilot and air traffic control during the dropsonde operations in open air space. The flight was successful, with 25 good sondes dropped from the GH in coordination with the G-IV. The data are currently being analyzed, and we expect a manuscript describing the intercomparisons to eventually be completed. To accommodate the mission, NASA is building a Global Hawk operations center at the Wallops Flight Facility where pilots will control the aircraft remotely, and scientists will command their instruments and receive data in real time. In addition, the Agency is expected to develop a mobile operations center so that the aircraft can deploy virtually anywhere. For further information, please contact Scott Braun (scott.a.braun@nasa.gov).

4.3. DISCOVER-AQ

Ken Pickering (614), Project Scientist for the Earth Venture-1 Deriving Surface Conditions from Vertical Profile and Remotely Sensed Data Relevant to Air Quality (DISCOVER-AQ) mission, reported that the project got off to a great start right on time on Friday, July 1 with the first science flights of the NASA P-3B from Wallops and NASA UC-12 from Langley. This was followed with a second set of flights on Saturday, July 2. This sequence of Friday/Saturday flights provided a contrast of pollution conditions on a weekday versus a weekend, albeit a holiday weekend. Both flights were conducted with the late takeoff scenario (10:30 a.m. departure). This allowed characterization of pollution during the Friday afternoon, get-away, high traffic volume, followed by likely, much lower traffic conditions by Saturday afternoon. A third set of flights was conducted on Tuesday, July 5 with an early morning (5:30 a.m.) departure to capture emissions from the morning rush hour on the day following the holiday weekend. The three sets of flights combined have provided 58 profiles of in situ trace gas and aerosol sampling, and a total of ~24 hours of gas and aerosol remote sensing. Initial analyses of the data are aimed at relating surface air quality with column and profile measurements from the aircraft and column observations from surface instruments and satellites.

The successful completion of the Baltimore-Washington deployment occurred on Friday, July 29. Fourteen flight days were conducted using the Wallops Flight Facility P-3B aircraft for in-situ sampling and the LaRC UC-12 (King Air) aircraft for remote sensing. During the month-long deployment, 254

aircraft spiral-altitude profiles of trace gases and aerosols were conducted over six Maryland Department of the Environment surface air quality monitoring stations. The airborne program was supplemented by an extensive array of ground-based instruments, which included Pandora UV/VIS spectrometers for trace gas column observations, AERONET sun photometers for aerosol optical depth, and a network of lidar observations. The mission was extremely successful in capturing a wide variety of air quality conditions (ranging from very clean to very polluted) over the month of July. The project has accumulated a large archive of observations with which to lead into the analysis and modeling phase and investigate the connections between the vertically resolved and column density observations and surface air quality. Future deployments will occur in 2013 and 2014. For further information, please contact Ken Pickering (kenneth.e.pickering@nasa.gov).

4.4. ECO-3D: Exploring the Third Dimension of Forest Carbon

Charles Gatebe (GESTAR/USRA, 613), Rajesh Poudyal (SSAI/613), Miguel Román (619) and Kurt Rush (564) participated in a field campaign, ECO-3D, out of Wallops Flight Facility on the NASA P3 aircraft. The campaign duration was three weeks in August-September, 2011 and covered areas as far north as Quebec, Canada and as far south as the Florida Everglades, USA. Three primary instruments developed at GSFC were involved in this campaign: Cloud Absorption Radiometer (CAR), [PI Charles Gatebe], the Digital Beamforming SAR (DB-SAR) [PI Rafael Rincon/Lola Fatoyinbo/Jon Ranson] and Swath Imaging Multi-polarization Photon-counting Lidar (SIMPL) [PI David Harding]. The instrument suite provided novel, complimentary information on forest canopy structure properties. The campaign acquired data for six, well-characterized ecology study sites from Quebec to Florida, in order to assess new methods for forest biophysical parameter estimation including above-ground biomass. The campaign also acquired data for two planetary-analog surfaces, sand dunes, and glacial boulder fields to evaluate retrieval of roughness characteristics at multiple length scales. For further information, please contact Charles Gatebe (charles.k.gatebe@nasa.gov).

4.5. GPM Ground Validation

In addition to focused field efforts such as MC3E and GCPEX, the GPM Ground Validation (GV) program instrumentation were used near Huntsville, Alabama to observe the rare southern snow event of January 10, 2011. Several advanced radars, a large collection of snow particle measurement instrumentation, and a 3D lightning location array were deployed to measure precipitation contents and wind-flow while ground-based camera and laser imaging systems measured individual snowflake sizes, the rate of fall of the snowflakes, and the amount of melted water associated with the snowfall.

More recently, GPM GV initiated the development of a high-density rain gauge, disdrometer, and multi-parameter radar precipitation research and error characterization facility on the Delmarva Peninsula managed by the Wallops Field Support Office (W. Petersen). This network will represent a globally unique method to observe the spatial and temporal variability of precipitation in all three dimensions across meteorological regimes types. It will also examine how this variability is represented across spatial and temporal scales in physically based precipitation retrieval algorithms and model data assimilation. For further information, please contact Walt Petersen (walter.petersen@nasa.gov).

4.6. GCPEX

The GPM Cold Season Precipitation Experiment (GPCEX) is a collaborative field effort between the NASA GPM and Environment Canada (EC). The field experiment has been designed to study the physical characteristics of falling snow in support of the development and testing of GPM core and constellation-satellite snowfall retrieval algorithms. Walt Petersen (610.W) and Gail Skofronick-Jackson (612) are the NASA GPM lead investigators for the campaign. Intensive planning and preparation for the GCPEX campaign took place in 2011, to include pre-field-campaign deployments of ground instrumentation in December. The campaign will begin in mid-January 2012 and run through February 2012. Platforms involved include the NASA DC-8 aircraft carrying the APR-2 radar and CoSMIR radiometer; the University of North Dakota Citation and Canada National Research Council Convair 580 carrying in situ microphysical probes, several advanced dual polarimetric and multi-frequency radars such as the NASA D3R radar and EC King City Radar; and an array of ground-based disdrometer, snow weighing gauge, and radiometer instrumentation. For further information, please contact Walt Petersen (walt.petersen@nasa.gov) or Gail Jackson (gail.s.jackson@nasa.gov).

4.7. SEAC4RS

The NASA-NSF-NRL Southeast Asia Composition, Cloud, Climate Coupling Regional Study (SEAC4RS) will address key questions regarding the influence of Asian emissions on clouds, climate, and air quality. SEAC4RS will utilize a variety of ground-based, aircraft, and satellite observations.* The SEAC4RS flight observation period will take place in August and September 2012, but ground-based and satellite observations and studies have already been conducted for several years as part of the seven Southeast Asian Studies (7-SEAS) Mission. 7-SEAS was established in 2007 to characterize aerosol-meteorological interactions in South East Asia. The 7-SEAS program was organized through a collaborative effort with the U.S. State Department and governments in Southeast Asia, NCAR Research Applications Laboratory, NASA, and the Office of Naval Research international field offices. SEAC4RS provides an intensive aircraft observation component that has been missing in the long term 7-SEAS mission, and in turn 7-SEAS provides data necessary to place the short-term SEAC4RS results in context over longer time periods. Atmospheres members, Judd Welton and Si-Chee Tsay, have been part of the 7-SEAS and SEAC4RS planning teams, and their NASA Micro-Pulse Lidar Network (MPLNET) and SMARTLabs projects have participated in both 7-SEAS and SEAC4RS missions since the beginning. Ground-based data have been collected in Singapore, Thailand, Taiwan, and Vietnam. More ground stations will be installed prior to, and during, the SEAC4RS field campaign in summer 2012. In addition, other Laboratory members will participate in the airborne portion of SEAC4RS in 2012 as part of both instrument and modeling/forecast teams. More information about 7-SEAS and SEAC4RS data is available at http://mplnet.gsfc.nasa.gov with contact Judd Welton (judd.welton@nasa.gov), and http://smartlabs.gsfc.nasa.gov with contact Si-Chee Tsay (si-chee.tsay@nasa.gov).

** At the time of this publication , the aircraft portion of this campaign has been cancelled.*

4.8. DYNAMO/CINDY2011

DYNAMO/CINDY2011 is an international field program that took place in the central equatorial Indian Ocean in late 2011 through early 2012 to collect in situ observations to advance our understanding of the Madden-Julian Oscillation (MJO) initiation processes and to improve MJO prediction. The Wallops Field Support office John Gerlach (610.W) is providing a C-band research radar (the TOGA radar), which is

installed on the R/V Revelle as a part of a sounding radar array formed by research vessels and island sites, and enhanced moorings inside and near the array. The design of the field campaign and the selection of observational objectives (e.g., vertical profiles of moistening and heating, structure and evolution of cloud and precipitation processes, surface fluxes, atmospheric boundary-layer and upper-ocean turbulence and mixing) have been and will continue to be guided by the DYNAMO modeling activities, which provide hypotheses on potentially crucial processes of MJO initiation. For further information, please contact John Gerlach (john.c.gerlach@nasa.gov).

4.9. Operation IceBridge

The Airborne Topographic Mapper (ATM) program at Wallops (610.W) continues to support NASA's Operation Ice Bridge (Studinger/615) through the HBSSS contract (Sigma Space). ATM IceBridge support includes:

- Management and leadership (John Sonntag, IceBridge Instrument Team lead, William Krabill IceBridge ATM Co-PI)
- Mission flight planning for IceBridge deployments (40 to 60 planned missions with 20 to 40 actually executed on deployment)
- ATM GPS, navigation, and dual ATM lidar installation on NASA P3 or DC-8 aircraft platforms
- ATM instrument operation on IceBridge flights and provision/quality assurance of precise GPS precise navigation to aircraft ILS
- ATM/GPS data processing, data calibration, and analysis
- Upload of ATM lidar elevation data to the National Snow and Ice Data Center (NSIDC) within six months of data collection

Since 1993, the ATM team has supported a total of 271 Arctic and Antarctic research missions. Most recently the ATM team supported 37 of the 271 mission total aboard the NASA P3 aircraft during a deployment to Greenland (Arctic land and sea ice missions). The team further supported a NASA DC-8 deployment to Punta Arenas Chile for 24 more missions conducted during the fall of 2011 (24 Antarctic land and sea ice missions). ATM Sampling over the Antarctic during the fall of 2011 generated much excitement as some of the first airborne Lidar observations of a major calving/fracturing event were collected over the Pine Island Glacier. All data from missions up to the spring of 2011 have been uploaded to the National Snow and Ice Data Center (NSIDC) and the Fall 2011 data are currently being processed for archive at NSIDC.

Since late 2011, the team has been in preparation for 2012 Arctic IceBridge deployments, a multi-agency collaboration with land and sea ice scientists. Over 60 mission flight plans have been developed and prioritized for use under various weather and aircraft schedules. Instrument upload and flight testing is underway with departure for Thule Greenland scheduled for March 12, 2012. For further information, please contact William Krabill (william.b.krabill@nasa.gov).

Recent papers by ATM team members:

TGRS-2011-00793 Validating ICESat over thick sea ice in the northern Canada Basin, L.N. Connor, S.L. Farrell, D.C. McAdoo, W.B. Krabill, and S. Manizade (in press)

Arctic sea ice freeboard from IceBridge acquisitions in 2009: Estimates and comparisons with ICESat, R. Kwok, G.F. Cunningham, S.S. Manizade, and W.B. Krabill; 2012, *J. Geophys. Res., 117, C02018, doi:10.1029/2011JC007654.*

Field Campaigns

The table below lists the various instrument systems used in the 2011 campaigns with the instrument scientists responsible for development of the systems and who managed and coordinated the field activities associated with their system. The importance of these campaigns cannot be over emphasized for the value they provide to science as well as the missions they support. They can provide for simulation of future flight instruments, development of data processing algorithms, calibration and validation of measurements, and operational details that can minimize risks of future failures.

Table 4.1: Instrument Scientists/Managers

Name	Instrument Systems	2011 Campaigns
Gerry Heymsfield	HIWRAP	MC3E and HS3
William Krabill	ATM	Operation IceBridge
Bruce Gentry	TWILITE	HS3
Mathew McGill	UAV-CPL	HS3
Charles Gatebe	CAR	ECO-3D
John Gerlach	NPOL	MC3E
John Gerlach	TOGA Radar	DYNAMO/CINDY2011
James Wang/Gail Jackson	CoSMIR	MC3E and GCPEX
Jay Herman	Pandora UV/VIS	DISCOVER-AQ
Judd Welton	MPLNET	SEAC4RS
SI-Chee Tsay	SMARTLabs	SEAC4RS

5. AWARDS AND SPECIAL RECOGNITION

5.1. Goddard and NASA Awards and Special Recognition

Table 5.1: List of GSFC Awards Received in CY 2011

GSFC Award	Recipient
Exceptional Achievement for Administrative	Omega Williams
Exceptional Achievement for Leadership	Arthur Hou
Exceptional Achievement for Mentoring	Lorraine Remer

Table 5.2: List of NASA Honor Awards Received in CY 2011

NASA Award	Recipient
Exceptional Achievement Medal	Joel Susskind
Exceptional Service Medal	Dennis Chesters
Outstanding Leadership Medal	James Gleason

Table 5.3: List of NASA Team Awards Received in CY 2011

Group Award	Recipient(s)
Atmospheric InfraRed Sounder (AIRS)	Joel Susskind, Oreste Reale, Bob Rosenberg, John Blaisdell, Lena Iredell, Gyula Molnar, Thomas Hearty, Louis Kouvaris, Pankaj Jaiswal, Joyce Tompkins
Global Hawk Pacific Mission (GLOPAC)	Paul Newman, Peter Colarco, Scott Janz, Stephan (Randy) Kawa, Gi-Kong Kim, Matthew McGill, Shane Wake, William Hurt, Dennis Hlavka, Matthew Kowalewski, Kent McCullough, Eric Nash, Stephen Palm, John Yorks, Daniel Reed, Leslie Lait, Michael Carlowicz
Genesis & Rapid Intensification Processes (GRIP)	Gerry Heymsfield, Scott Braun, Amber Emory, Lin Tian (Morgan State University)
Joint Polar Satellite System Transition (JPSS)	Jim Gleason
The Laser Risk Reduction Program (LRRP)	Bill Heaps

5.2. External Awards and Special Recognition

Paul Newman, Chief Scientist for Atmospheres, has been named as a 2012 Fellow of the American Meteorological Society (AMS). Election to grade of Fellow serves as a recognition of his outstanding contributions to the atmospheric or related oceanic or hydrologic sciences, or his application, during a substantial period of years. A maximum of only two-tenths of one percent of the AMS membership is approved through the Fellow nomination process.

Awards and Special Recognition

William Lau (610) has been selected as a member of the new National Academy of Science Committee on Himalayan Glaciers, which studies the impact of climate change on accelerated melting of Himalayan glaciers and impacts on downstream populations. The committee is composed of experts from diverse disciplines including high mountain glaciers, atmospheric scientists, hydrologist, paleo-climatologist, demographers, economists, and social and political scientists. It is charged with providing an assessment of current knowledge of Himalayan glaciers and possible future scenarios of physical changes and stress on water resources in Asia. Lau will contribute his expertise in the areas of remote sensing and modeling of the effects of aerosol atmospheric heating, and darkening of snow surfaces by black carbon and dust on the Asian monsoon.

Arthur Hou, GPM Project Scientist, was selected to serve on EUMETSAT's Satellite Applications Facility Proposal Evaluation Board, which met on January 25–27 at EUMETSAT Headquarters in Darmstadt, Germany.

Matt McGill and **Dennis Hlavka** shared in a prestigious Naval Research Laboratory award for an outstanding publication, as coauthors, during the annual NRL awards banquet in March.

Lazaros Oreopoulos (613) has accepted an invitation to serve a two-year term in the Science Director's Council (SDC), representing Code 610. The Council serves as a conduit of communication with the Director of Sciences and Exploration and other senior leaders on matters concerning the health and vibrancy of science at GSFC and is a source of input and visibility for those scientists newest to GSFC.

Santiago Gasso (UMBC-GEST/613) became an Adjunct Professor at the North Carolina State University. He will be a member of the PhD committee for Matthew Johnson, a graduate student advised by Professor Nicholas Meskhidze.

Chris Kidd served as deputy chair on the research award panel for the International Opportunity Fund at the Natural Environment Research Council, UK on March 25 overseeing $9M of requested funding.

Eyal Amitai (612/Chapman University) was appointed as an Associate Editor for the AMS *Journal of Hydrometeorology.*

Joe Munchak (612/ESSIC) was selected to receive the AMS Robert Leviton Award for his paper: "A Modular Optimal Estimation Method for Combined Radar–Radiometer Precipitation Profiling" (Munchak, S.J. and C.D. Kummerow, 2011*: J. Appl. Meteor. Climatol.,* 50, 433-448). The Robert Leviton Award is presented for the best student paper on the development or evaluation of atmospheric instrumentation or unique measurement techniques.

6. EDUCATION AND OUTREACH

6.1. Introduction

Atmospheric scientists in the Earth Sciences Division actively participate in NASA's efforts to serve the education community at all levels and to reach out to the general public. Scientists seek to make their discoveries and advances broadly accessible to all members of the public and to increase their understanding of why and how such advances affect their lives through formal and informal education and in public outreach avenues. Activities include continuing and establishing collaborative ventures and cooperative agreements; providing resources for lectures, classes, and seminars at educational institutions: and mentoring or academically-advising all levels of students. The following sections summarize many such activities.

The laboratories supported a range of programs intended to inspire and develop a future generation of Earth scientists. Among these programs are: The Practical Uses of Math and Science (PUMAS), https://pumas.gsfc.nasa.gov/; The Summer Institute in Earth Sciences (SIES) and Graduate Student Summer Program (GSSP) managed by GEST, http://gest.umbc.edu/student_opp/students.html; graduate student advising, teaching university courses, the NASA Postdoctoral Program (NPP), http://nasa.orau.org/postdoc/description/index.htm; and interactions with Howard University. The latter activity is discussed below as an example of collaboration with special emphasis on recruiting and training underrepresented minorities for careers in Earth Science.

6.2. Interactions with Howard University

6.2.1. Partnerships with Howard University/University Research Center-BCCSO

A part of NASA's mission has been to initiate broad-based aerospace research capability by establishing research centers at the nation's historically black colleges and universities (HBCU). The Beltsville Center for Climate Change observation (BCCSO) was established as a part of this initiative in 2009 through a competitive award, in partnership with Howard University in Washington, DC. This program, which consists of teaching and research, has collaborations across the Laboratories. An extended description of this collaboration is available at http://bccso.org. It has also been a goal of the Earth Sciences Division to partner with BCCSO to establish a self-supporting facility at Howard University for the study of terrestrial and extraterrestrial atmospheres with special emphasis on recruiting and training underrepresented minorities for careers in Earth and space science.

Participation with Howard University on the Beltsville Campus Research Site

For several years, Howard University has been in the process of building a multi-agency, multi-university field observation research station at the Howard University Research site at Beltsville (HURB). This research facility is part of the NOAA-Howard University Center for Atmospheric Science (NCAS). Bruce Gentry (612), Gerry Heymsfield (612), Alexander Marshak (613), David Whiteman (612), Belay Demoz (formerly of GSFC, now at Howard University), and others from GSFC are mentoring students and participating in field research at this site. One of the main instruments there is a world-class Raman lidar built with major involvement from Code 612.

6.2.1.1 WAVES

During the summers of 2006 and 2007 and the winters of 2009 and 2011, students from Howard University participated in the Water Vapor Validation Experiments Satellite and Sondes (WAVES) field campaigns at the Beltsville site. The WAVES activities are focused on providing data for satellite validation and intercomparison of various remote and in situ sensing technologies. One of the main goals has been to acquire statistically robust sets of measurements of atmospheric water vapor, aerosols, and trace gases useful for Aura/Aqua satellite retrieval studies as well as to perform instrument accuracy assessments and case studies of regional water vapor and aerosol variability. WAVES_2006 was the first major experiment held at HURB and required coordination within Howard University and with GSFC, NOAA/Boulder, NWS/Sterling. Many universities were involved as well, including the University of Maryland, College Park; the University of Maryland, Baltimore County; Pennsylvania State University; Bowie State, MD; Trinity University, DC; the University of Virginia, Charlottesville; Smith College, NH; the University of Wisconsin; and with universities in Brazil, Italy, and Bolivia. The initial WAVES activities were funded by NASA/SMD under the AURA validation program for two years and have been carried forward as components of the Atmospheric Chemistry program in support of the Network for the Detection of Atmospheric Composition Change. For further information see the WAVES Web site, http://tropometrics.com, or contact David Whiteman (david.n.whiteman@nasa.gov) or Belay Demoz (bbdemoz@howard.edu).

6.2.1.2 Wind Lidar Intercomparison

In 2010, a three-year program to assess performance of ground based wind lidar was completed at the Howard University, Beltsville campus. The goal of the experiment was to compare two of NASA's state-of the-art wind lidar technology instruments and candidates for NASA's Decadal Survey 3D-Winds Mission: the VALIDAR, an aerosol-based lidar system from NASA's LaRC; and the GLOW, a molecular-based Doppler lidar from GSFC. This is the first experiment where these two techniques have been compared in side-by-side experiments. In addition, the commercial wind lidar from Leosphere, France (the WLS70(c)), a 915 MHz profiler, ACARS winds, and different types of radiosondes were also included.

The wind lidar intercomparison experiment was funded by NASA's SMD for three years under as part of the wind lidar science program. For further information, contact Bruce Gentry (bruce.m.gentry@nasa.gov) or Belay Demoz (bbdemoz@howard.edu).

6.2.1.3 DABUL

A new MPL-like lidar, called the Depolarization and Backscatter Unattended Lidar (DABUL), is being installed at HURB in collaboration with UMBC and Judd Welton (612). Timothy Berkoff of UMBC has started the work, which is ongoing. The lidar is to be operating from HURB, and its data is to be used for satellite validation as well as air pollution studies. For further information, please contact Timothy Berkoff (timothy.a.berkoff@nasa.gov) or Judd Welton (ellsworth.j.welton@nasa.gov).

6.3. Lectures and Seminars

One aspect of public outreach includes lectures and seminars held each year and announced to all our colleagues in the area. Most of the lecturers are from outside NASA, and this series gives them a chance to visit with our scientists and discuss their latest ideas from experts. The following were the lectures presented in 2011 among the various laboratories.

Table 6.2: Atmospheric Sciences Distinguished Lecture Series

Date	Speaker	Title
February 17	Duane E. Waliser JPL	*The MJO: Some Updates on Science, Forecasting and Impacts*
March 2	Gerald Heymsfield NASA GSFC	*Deep Convection—What we know about structure, regional difference and evolution*
April 21	Qiang Fu University of Washington	*Observational evidence of atmospheric circulation changes in last three decades: Challenges to modeling, observations, and our understanding*
May 19	Darryn W. Waugh Johns Hopkins University	*Antarctic Ozone Hole and Southern Hemisphere Climate and Weather*
June 1	In-Sik Kang Seoul National University, Korea	*Some thoughts and an attempt at cloud microphysics in a GCM*
June 16	Ann M. Fridlind NASA GISS	*Formation and evolution of ice in mixed-phase clouds: Towards observationally constrained simulations*
October 20	Colin Helmer George Washington University	*The Global Climate Change Negotiations*
November 17	Howard Bluestein University of Oklahoma	*Rapid-scan, mobile Doppler-radar observations of tornadoes and their parent supercells*

6.3.1. Laboratory Seminars

Table 6.3: Mesoscale Atmospheric Processes

Date	Speaker	Title
June 21	Masaki Satoh and Tempei Hashino AORI, University of Tokyo	*Global nonhydrostatic simulation by 3.5km-mesh NICAM and validation of cloud microphysical statistics simulated by a global cloud-resolving model with active satellite measurement*
June 28	Igor Veselovskii, USRA, Physics instrumentation Center, Russia	*Multi-wavelength lidar studies and their relation to the ACE mission*
June 29	Efi Foufoula-Georgiou and Mohammad Ebtehaj, University of Minnesota	*Adaptive Fusion of Multi-sensor Precipitation Observations using Gaussian Scale Mixtures in the Wavelet Domain*
June 30	Marcos Andrade Universidad Mayor de San Andres, La Paz, Bolivia	*Aerosol particle transport to the Bolivian Andean Glaciers: Preliminary results and future steps*
August 8	Jon Reisner Los Alamos National Laboratory	*The advection-condensation problem in hurricane intensity modeling: Impact and possible solutions*

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Date	Speaker	Title
October 28	Fuqing Zhang Pennsylvania State University	*Assimilation of High-Resolution Inner-core Observations for Cloud-Resolving Hurricane Initialization*
November 15	Chris Thorncroft and Jason Dunion, State University of New York at Albany / University of Miami, NOAA HRD	*Tropical Cyclone variability in the east Atlantic*

Table 6.4: Climate and Radiation

Date	Speaker	Title
January 5	Robert Levy SSAI and NASA GSFC	*Synergy of Atmospheric Aerosol Information: The importance of "getting it right"*
January 5	Charles Ichoku NASA GSFC	*New look at biomass burning in the world of changing climate*
February 10	Alex Kostinski, Michigan Technological University	*Speedy Raindrops*
March 2	Thomas L. Bell NASA GSFC (Emeritus)	*Statistical Pitfalls in Multi-Hypothesis Testing and Detecting Weekly Cycles*
March 16	Belay B. Demoz Howard University	*Atmospheric Research at the Beltsville Research Campus: Contribution to Science, Education and Inter-Agency Collaboration*
April 6	Dong Huang, Brookhaven National Laboratory	*Three-dimensional Cloud Structure: from observations to parameterizations in large-scale models*
April 20	Olga Kalashnikova NASA/Jet Propulsion Laboratory/ California Institute of Technology	*MISR observations of mineral dust: optical modeling, property characterization, and climate applications*
May 4	Yaping Zhou UMBC-GESTand NASA GSFC	*Recent trends of the tropical hydrological cycle inferred from satellite observations—from large-scale to tropical cyclones*
June 1	Susanna Bauer Columbia University & NASA GISS	*Aerosol Forcings and Feedbacks: Understanding the differences between direct, indirect, and semi-direct forcings and feedbacks*
June 15	Jeffrey B. Halverson UMBC	*Hunting Hurricanes: NASA's Field Programs Exploring Hurricanes Using Satellites, Supercomputers, and High Altitude Aircraft*
September 22	Hiroko Miyahara Institute for Cosmic Ray Research, The University of Tokyo	*Galactic Cosmic Rays and Climate Change at the Maunder Minimum*
October 5	Kyu-Myong Kim GESTAR/Morgan State University and NASA GSFC	*The role of African easterly wave on dust transport and the interaction between Saharan dust layer and Atlantic ITCZ during boreal summer*

Date	Speaker	Title
October 19	Tamas Varnai University of Maryland-JCET	*Clouds, aerosols, and 3D radiative processes*
November 10	Alex Kokhanovsky Bremen University, Institute of Environmental Physics	*Hyperspectral Remote Sensing of Terrestrial Atmosphere using SCIAMACHY*
November 16	Maksym Petrenko University of Maryland and NASA GSFC	*Multi-Sensor Aerosol Analysis*
November 30	Guoyong Wen GESTAR/Morgan State University and NASA GSFC	*Temperature Reponses to Spectral Solar Forcing on Decadal and Centennial Time Scales*

Table 6.5: Atmospheric Chemistry and Dynamics

Date	Speaker	Title
February 17	Randy Kawa NASA GSFC	*Comparing Global Atmospheric CO2 Flux and Transport Models with Observations*
March 3	Apostolos Voulgarakis NASA GISS	*Steps Toward Understanding Tropospheric Oxidant Variabilt*
March 16	Judith Lean NRL	*Climatology of the Lower Stratospher*
March 17	William Stockwell Howard University	*The Regional Atmospheric Chemistry Mechanism, Version 2; Analysis of the Effects of Daytime and Nighttime Atmospheric Chemistry on Forecasts of Tropospheric Ozone and Aerosol Formation*
March 31	Anne Prados UMBC and NASA GSFC	*NASA Air Quality Capacity Building Activities: Bridging the gap between science and policy*
April 4	Christopher Schwaim Clark University	*On Hydroclimatic Induced Excursions in Biospheric NEE from 1948 to Present*
May 5	J. Pepijn Veefkind KNMI	*Troposhere Ozone Monitoring Instrument (TROPOMI)*
May 19	Peter Colarco NASA GSFC	*The GEOS-5 Aerosol Forecasting System and the International Cooperative for Aerosol Prediction (ICAP)*
May 26	Nickolay Krotkov NASA GSFC	*Introduction to the new SO_2 Laboratory website*
June 16	Kenneth Pickering NASA GSFC	*The Earth Venture-1 DISCOVER-AQ Mission*

Date	Speaker	Title
June 30	Mike Newchurch University of AL	*Boundary Layer and Free Tropospheric Ozone Spatio-Temporal Variability*
August 18	Henry Selkirk USRA and NASA GSFC	*The Vertical Structure of the Tropical Tropopause Layer and the Water Vapor Tape Recorder*
August 25	Elena Spinei Washington State	*Measuring BrO in Fairbanks, Alaska*
September 29	James Wang NOAA-ARL	*Constraining Climate Trends at the Tropical Tropopause*
October 6	Richard Damoah USRA and NASA GSFC	*Time Integrated Radiative Forcing from North American NOx Emissions*
November 3	Luke Oman NASA GSFC	*Modeling and Observations of the Response of Tropical Tropospheric Ozone to ENSO*
December 1	Valentina Aquila NASA GSFC Postdoctoral Program Fellow	*The Interaction between Mt. Pinatuba Aerosols and the Stratosphere*

6.4. Interactions and Crosscutting

6.4.1. AeroCenter

Aerosol research is one of the nine crosscutting themes of the Earth Sciences Division at NASA's Goddard Space Flight Center. The AeroCenter is an interdisciplinary union of researchers at Goddard and other organizations in the Washington D.C. metropolitan area (including NOAA NESDIS, universities, and other institutions) who are interested in the many facets of atmospheric aerosols. Interests include aerosol effects on radiative transfer, clouds and precipitation, climate, the biosphere, and atmospheric chemistry the aerosol role in air quality and human health, and the atmospheric correction of aerosol blurring of satellite imagery of the ground. Our regular activities include strong collaborations among aerosol community, bi-weekly AeroCenter seminars, annual poster session, and annual AeroCenter update.

In the 2010 through 2011 season, the AeroCenter invited 32 seminars with typical 30 to 40 physical attendees, and 5 to 10 WebEx® attendees most of whom were from outside GSFC. For more than 10 years, the AeroCenter has played a primal role in exchanging up-to-date aerosol science across NASA laboratories and other institutions since 2001, initiated by Lorrain Remer and Yoram Kaufman. Recent major topics included 1) updates of aerosol retrieval algorithms using the Aqua/Terra MODIS, the Terra MISR, the Aura OMI, the SeaStar SeaWiFS, and the CALIPSO CALIOP sensors; 2) updates of algorithm and networks of in-situ aerosol measurements from the AERONET; and 3) evaluation of aerosol transport simulations from the GEOS-5 and the GOCART models against satellite and in-situ datasets. For further information, please contact Toshihisa Matsui (toshihisa.matsui-1@nasa.gov).

In conjunction with the Wallops Aircraft Office (830), Bland engaged Virginia Tech in preparations for flying the SPARRO UAV (C. Wosley) to support instrument tests. A pair of SBIR-developed instrument prototypes, the Aeroprobe 3D wind sensor and the Vista Photonics carbon dioxide sensor, will be flown concurrently.

6.5. Public Outreach

February

Alexander Marshak (613) gave an informal presentation entitled "Spectral Invariance in Atmospheric Radiation" at the Department of Atmospheric and Oceanic Sciences, University of Colorado Boulder, February 4.

David Wolff (612) presented a talk to the National Commission on Teaching and America's Future (NCTAF) on February 9 at the NASA GSFC Visitor's Center entitled: "Measuring Precipitation Using Radars, Rain Gauges and Disdrometers." This is the beginning of collaboration between NASA and teachers from Howard County who are interested in precipitation estimates. Specifically, teachers from Wilde Lake High School classes are building weather instruments and then going on a field trip to gather information with them.

Eyal Amitai (Chapman University/612) participated as a judge in the Science Fair at Greenbelt Elementary on February 9.

David Whiteman (612) participated as a judge in the Science Fair at Springhill Lake Elementary on February 4. He and **Kevin Vermeesch** (SSAI/612) helped to judge the STEM Fair at Greenbelt Middle School on February 11.

David Starr (612) participated as a judge in the Science Fair at Rockledge Elementary on February 17.

March

Scott Braun (612) gave a talk entitled "Hurricanes: How Technology Helps Minimize Disaster" to a group of 40–50 elementary and middle school teachers at the Maryland Science Center in Baltimore on March 19.

John Yorks (SSAI/612) presented a talk on March 31 titled "NASA Goddard Airbourne Lidar Studies: Measurements of Cloud and Aerosol Properties" at the Millersville University Earth Science Department Seminar.

April

John Gerlach (610.W) and the NPOL radar team welcomed local visitors and news media to the MC3E site to observe operations and learn about the experiment.

May

Kevin Ward (Sigma Space/HBSSS/613) participated in the 2011 Science on a Sphere Users Collaborative Network Workshop at the Museum of Science & Industry in Chicago, IL, May 3-5. He presented several demonstrations using NASA Earth science data imagery from NEO (NASA Earth Observations) http://neo.sci.gsfc.nasa.gov/ and was a panelist on "Connections to Other Platforms and Networks."

GEORGE J. HUFFMAN (SSAI; 612), **CHRISTOPHER KIDD** (ESSIC; 612), and **GAIL SKOFRONICK-JACKSON** (612) served as part of the staffing for the GPM booth at the Explore@NASA Goddard public open house, May 14, GSFC. As part of this activity, Drs. Kidd and Huffman developed a handout depicting the climatology of global precipitation from the Global Precipitation Climatology Project and suitable for cutting out and folding into a 26-facet "sphere," then worked with Dalia Kirschbaum (617) on NASA approval and production. In the event, there was a continuous line from the opening (11 a.m.) to 2:30 p.m., which slowly tapered to occasional visitors by 4:00 p.m.

WALT PETERSEN (610.W) presented an overview of the GPM Mid-Latitude Continental Convective Clouds Experiment, and answered questions about the experiment and GPM at the MC3E Press Day held at Offutt AFB, Nebraska.

June

JOE MUNCHAK (ESSIC/612) gave a presentation entitled "Insights from a Decade of NASA's Earth Observing Missions" at the 3rd annual Thomas Jefferson Symposium To Advance Research (TJSTAR) at Thomas Jefferson High School for Science and Technology in Alexandria, VA on June 1. This presentation covered the various earth observing satellites NASA has launched in the past 10 to 15 years and the key discoveries their measurements have made towards climate change research. Examples include temperature, water vapor, and radiation budget measurements, cloud and aerosol properties, and precipitation. Major technologies behind these measurements were also discussed.

JIM IRONS (610) delivered a keynote address to a Tribal College and University workshop on June 9 at Haskell Indian Nations University, Lawrence, KS. The workshop is part of a student "externship" program sponsored by the NASA Tribal College and Universities Project.

ROBERT CAHALAN (613), President of the International Radiation Commission (IRC), is convening the IRC Annual Business Meeting, June 30. The IRC is sponsoring/co-sponsoring 4 International Association of Meteorology and Atmospheric Sciences (IAMAS) sessions at the IUGG. **ALEXANDER MARSHAK** (613) is convening the session on Three Dimensional Radiative Transfer in the Atmosphere and **LAZAROS OREOPOULOS** (613) is reporting on the status of the Continual Intercomparison of Radiation Codes (CIRC).

LARRY BLIVEN (610.W) mentored an undergraduate student from Brown University during the summer, providing guidance in the engineering, data analysis and software design for the Precipitation Video Imager.

JOHN MOISAN (610.W) mentored two undergraduate students in the summer of 2011. Mr. Charles Moon and Mr. Richard Landa (University of Maryland). Mr. Moon worked on analyzing actual sea level observations along the Chesapeake Bay to provide in situ validation on the previous 3D analysis. Mr. Landa worked on supporting the OASIS ocean deployment over the summer.

JOHN MOISAN (610.W) is serving as a PhD Committee Member for Ms. Amanda Plagge of Univ. of New Hampshire. Doug Vandemark (UNH) is the committee chair.

July

A delegation of Korean officials and scientists from the Koren Ministry of Environment (MoE) visited NASA Headquarters and GSFC on July 7 to discuss collaboration on Korean's Geostationary Environmental Monitoring Sensor (GEMS). They visited the Atmospheres instrumentation and cleanroom lab in building 33, and toured GSFC JWST and GPM spacecraft test and integration facilities arranged by the GSFC Office of Communications. **PAWAN K. BHARTIA** (610) participated in a HQ briefing. **WILLIAM LAU** (610), **KYU-MYONG KIM** (613) and M. Kowaleswki participated in the GSFC portion of the visit.

On July 7–8, **NICKOLAY KROTKOV** (614) and **JIANPING MAO** (GESTAR/614) presented invited talks in a 2-day workshop at the Smithsonian Institution National Museum of Natural History about satellite remote sensing of volcanic emissions. Concerns were raised particularly by recent volcanic eruptions in Iceland, Chile and Africa about volcanic emissions of SO_2 and CO_2 gases. Dr. Krotkov gave a talk about NASA's historic (TOMS), current (Aura/OMI) and future (NPP/OMPS) SO_2 measurements and long-term global database for volcanic SO_2 data (http://so2.gsfc.nasa.gov). Dr. Mao, on behalf of PI Dr. James Abshire (GSFC 690.5), gave a talk about Goddard CO_2 laser sounder development toward future NASA carbon mission ASCENDS and potential use of laser techniques and Japanese GOSAT data to estimate CO_2 emissions from volcanic eruptions and degassing.

CHARLES GATEBE (USRA/613), **RITESH GAUTAM** (USRA/613), **PAWAN GUPTA** (USRA; 614) and **GYULA MOLNAR** (MSU/613) gave inspiring presentations on July 25–26 to 35 highly motivated, STEM-focused, high school students, who are enrolled for the 2011 Summer Academy of Mathematics and Science program at Morgan State University (MSU). This was in celebration of the Physics & Engineering Physics Week, June 20 –July 29 on MSU's campus.

SCOTT BRAUN (612) participated in the PhD Exam (July 28) for Sam Trahan at UMBC. Braun serves on Sam's PhD Thesis committee.

TIFFANY MOISAN (610.W) hosted a 5-day NASA Coastal Research Experience workshop at the Wallops Field Office during the week of July 11. The workshop brought NASA Explorer School teachers in from across the country to learn about satellite data, shipboard measurements, and laboratory experiments. This workshop was a joint venture of NASA GSFC, NASA LRC, NASA GRC, NASA Explorer Schools, National Science Teachers Association (NSTA), and the Virginia Marine Science Consortium.

August

AMBER REYNOLDS gave a talk on "Advances in Monitoring Tropical Cyclone Rapid Intensification" on Thursday, August 11 at the Visitor's Center to a group of high school junior and senior students from Connecticut as part of the Beginning Engineering Science and Technology (BEST) Program. This was part of the Go for Aerospace Summer Workshop 2011 that aims to inspire high school students to attend college and major in STEM disciplines.

WALT PETERSEN (610.W) served(s) as a PhD advisor for three PhD candidates located at the University of Alabama Huntsville, Ms. Elise Schultz (polarimetric radar studies of lightning cessation), Mr. Christopher Schultz (GOES-R Geostationary Lightning Mapper severe weather decision support algorithms), and Mr. Patrick Gatlin (polarimetric radar precipitation rate algorithms).

September

CHARLES JACKMAN (614) gave an invited presentation entitled "The Impact of Energetic Particle Precipitation Effects on the Atmosphere" at the National Research Council sponsored meeting entitled "The Effects of Solar Variability on Earth's Climate: A Workshop," held September 8–9 in Boulder, CO.

CHARLES ICHOKU (613) was an invited speaker at the 2011 Global Competitiveness through Diversity Conference, sponsored by National Society of Black Physicists and National Society of Hispanic Physicists, Austin, TX, September 21–24.

ROBERT CAHALAN (613) gave a webinar on September 21 and presented a talk entitled "Earth's Energy Budget: A Deeper Look" at the Earth to Sky V: Communicating Climate Change Workshop held at the US Fish & Wildlife Service National Conservation Training Center, Shepherdstown, WV, September 26.

WEI-KUO TAO (612) and **XIPING ZENG** (612) attended a meeting at City College of New York (CCNY) on September 26 to discuss the Goddard Cumulus Ensemble (GCE) modeling abilities (including recent improvements and performances to simulate convective systems occurring over land and ocean). In addition, they also met with Professors Johnny Lou (host, CCNY), D. Posselt (U. Michigan), and X. Huang (U. Michigan) to discuss collaborative research funded by current and future NASA proposals.

BO-WEN SHEN (UMCP/ESSIC/612) served as a PhD committee for Yi-Chih Huang at North Carolina A&T State University. The title of Huang's dissertation is "Numerical Studies of Orographic Effects on Tropical Weather Systems." Huang passed his preliminary oral exam on September 27.

October

WILLIAM LAU (610) met with a group of about 20 Earth Ambassadors and presented a lecture on "Aerosol, Clouds, Precipitation and Climate Change" at the Earth Ambassador Training held on October 13–14. The Earth Ambassador is a NASA HQ sponsored project aimed at providing climate change training to education professionals from museums, schools, and civic organizations. The Ambassadors will apply the knowledge they gain from the training to spur awareness, and hands-on climate science activities in their own communities.

WILLIAM LAU (610) was also featured at the Earth Science Week (October 9–15) Videos of Earth Sciences where he talked about the teleconnection of climate systems using, as an example, the Russian wild fires and the Pakistan flood the occurred during the summer of 2010. The video can be viewed at http://climate.nasa.gov/esw2011/MeetScientists/. An early online version of the paper "Teleconnection of Hydrometeorologic Extremes: The Russian Heat Wave and the Pakistan Flood of Summer 2010" can be found at http://journals.ametsoc.org/doi/pdf/10.1175/JHM-D-11-016.1.

DAVID WHITEMAN (612) met with Paolo Laj, Director of the Laboratory of Glaciology and Geophysics of the Environment, Grenoble, Fr, Marcos Andrade and Ricardo Forno of the Physics Department of the Universidad Mayor San Andres, La Paz, Bolivia (UMSA) to discuss the use of the newly established backscatter lidar at UMSA in monitoring the development of the daytime mixed layer in the vicinity of Mt. Chacaltaya (elevation 5.2 km). The lidar measurement capability has been developed over the past two years as a joint effort between NASA/GSFC and UMSA.

JUDD WELTON (612) visited Jakarta, Indonesia to meet with the Meteorological Climatological and Geophysical Agency (BMKG). BMKG will be assisting with AERONET and MPLNET deployments in Indonesia as part of the ongoing 7-SEAS and next year's NASA SEAC4RS field campaigns in South East Asia. Indonesia will be an important location for measurements during the SEAC4RS time period of August through September 2012 because all of the fire and smoke activity in the region is centered over Sumatra and Borneo. The overall plan is to compliment a Sumatran site near the actual fires with other sites downwind to track the smoke plumes, from Singapore to Borneo and north to Palawan, Philippines.

CHARLES JACKMAN (614) and **ANNE DOUGLASS** (614) were interviewed by a writer for *Discover Magazine* on October 4 concerning the scientific legacy of the Upper Atmosphere Research Satellite (UARS) mission. The UARS included ten instruments and measured energy inputs, dynamics, and chemistry of the middle atmosphere, of which some observations lasted over 14 years (September 1991–Dec. 2005). The UARS entered the Earth's atmosphere and fell in the South Pacific Ocean on September 24.

GAIL SKOFRONICK JACKSON (612) gave an invited seminar in the electrical engineering department at City College of New York (CCNY), New York City on October 6 entitled: "Spaceborne Active and Passive Retrievals of Falling Snow". During this visit, she also met with Prof. Bill Rossow (host) and his team

to discuss collaborative efforts between their surface snowpack research and Dr. Jackson's falling snow research. In addition, she also discussed with Professor Marco Tedesco potential instrumentation ideas for GPM's January through February 2012 falling snowfield campaign.

WALT PETERSEN (610.W) co-lead a light-precipitation data analysis workshop focused on the CloudSat/GPM Light Precipitation Validation Experiment (LPVEX) at the Finnish Meteorological Institute and University of Helsinki. Dr. Petersen interacted with Dr. Dmitri Moisseev (University of Helsinki) and Prof. Tristan L'Ecuyer (University of Wisconsin) to coordinate science analysis and use of precipitation datasets collected in Finland during LPVEX for GPM and CloudSat satellite retrieval algorithm validation activities.

TIFFANY MOISAN (610.W) and **BRIAN CAMBELL** (SAIC/GSFC/WFF) developed a completely unique multi-panel exhibit using "Lite-Brite®" and NASA SeaWiFS ocean color products to describe the Mid-Atlantic/Chesapeake Bay region. The exhibit will be on display at the Aquarium's Marsh Pavilion through the summer. It will then travel to the Visitor's Centers at the NASA Goddard Space Flight Center and the NASA Wallops Flight Facility.

November

TIANLE YUAN (UMBC-JCET/613) gave an invited seminar entitled "Evidence for Aerosol Enhancement of Lightning and Convective Invigoration" at the School of Marine and Atmospheric sciences of SUNY–Stony Brook, November 9.

WALT PETERSEN (610.W) participated in the PhD Qualifying Oral Exam for Kenneth Leppert II (University of Alabama Huntsville). Petersen serves on Ken's PhD Thesis committee.

TIFFANY MOISAN (610.W) interacted with high school students from Jefferson High School, an Obama school, at the Chesapeake Bay Tunnel Peer while she conducted physiology experiments to understand how phytoplankton respond to diurnal changes in light, temperature, tides and how coastal productivity changes over the day.

ACRONYMS

Acronyms defined and used only once in the text may not be included in this list. GMI has dual definitions. Its meaning will be clear from context in this report.

3D	Three Dimensional
7-SEAS	Seven SouthEast Asian Studies
ACE	Aerosols, Clouds, and Ecology
ACRIM	Active Cavity Radiometer Irradiance Monitor
AEROKATS	Advancing Earth Research Observation Kites And Tether Systems
AERONET	Aerosol Robotic Network
AETD	Applied Engineering and Technology Directorate
AIRS	Atmospheric InfraRed Sounder
ALVICE	Atmospheric Lindar for Validation, Interagency Collaboration and Education
AMA	Academy of Model Aeronautics
AMS	American Meteorlogical Society
AMSR-E	Advanced Microwave Scanning Radiometer–Earth Observing System
AMSU	Advanced Microwave Sounding Unit
AOD	Aerosol Optical Depth
AOT	Aerosol Optical Thickness
ARCTAS	Arctic Research of the Composition of the Troposphere from Aircraft and Satellites
ARM	Atmospheric Radiation Measurement
ASCENDS	Active Sensing of CO2 Emissions over Nights, Days, and Seasons
ASIF	Air Sea Interaction Facility
ASR	Atmospheric System Research
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ATM	Airborne Topographic Mapper
ATMS	Advanced Technology Microwave Sounder
BC	Black Carbon
BESS	Beaufort and East Siberian Sea
BEST	Beginning Engineering Science and Technology
BMKG	Meteorological Climatological and Geophysical Agency
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CAR	Cloud Absorption Radiometer
CCM	Chemistry-climate model
CCMVal	Chemistry Climate Model Evaluation
CCNY	City College of New York
CERES	Cloud and Earth Radiant Energy System

Acronyms

CF	Central Facility
CINDY	Cooperative Indian Ocean experiment on intraseasonal variability
CIRC	Continual Intercomparison of Radiation Codes
CLEO	Conference on Lasers and Electro-Optics
CO	Carbon Monoxide
CoSMIR	Conical Scanning Millimeter-wave Imaging Radiometer
CPL	Cloud Physics Lidar
CrIS	Cross-track Infrared Sounder
CRM	Cloud-resolving Models
CRS	Cloud Radar System
DB-SAR	Digital Beam-forming SAR
DISC	Data and Information Services Center
DISCOVER-AQ	Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality
DOD	Department of Defense
DOE	Department of Energy
DPR	Dual-frequency Precipitation Radar
DSCOVR	Deep Space Climate Observatory
DYNAMO	Dynamics of the Madden-Julian Oscillation
EC	Environment Canada
ECO-3D	Exploring the Third Dimension of Forest Carbon
ENSO	El Niño Southern Oscillation
EOF	Empirical Orthogonal Function
EOS	Earth Observing System
EPIC	Earth Polychromatic Imaging Camera
ESA	European Space Agency
ESSIC	Earth System Science Interdisciplinary Center
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
FMI	Finnish Meteorological Institute
FV	Finite Volume
GCE	Goddard Cumulus Ensemble
GCM	Global Climate Model
GCPEX	GPM Cold Season Precipitation Experiment
GEMS	Geostationary Environmental Monitoring Sensor
GEO-CAPE	Geostationary Coastal and Air Pollution Events
GEOS	Goddard Earth Observing System
GES	Goddard Earth Sciences

GEST	Goddard Earth Sciences and Technology Center
GESTAR	Goddard Earth Sciences Technology Center and Research
G-IV	Gulfstream IV
GLOPAC	Global Hawk Pacific Missions
GMAO	Goddard Modeling and Analysis Office
GMI	GPM Microwave Imager
GMI	Global Modeling Initiative
GOES	Geostationary Operational Environmental Satellites
GOES-R	Geostationary Operational Environmental Satellite – R Series
GOSAT	Greenhouse gases Observing Satellite
GPCEX	GPM Cold Season Precipitation Experiment
GPM	Global Precipitation Measurement
GRIP	Genesis and Rapid Intensification Processes
GSFC	Goddard Space Flight Center
GUV	Global UltraViolet
GV	Ground Validation
HAMSR	High Altitude Monolithic Microwave Integrated Circuit Sounding Radiometer
HBSSS	Hydrospheric and Biospheric Sciences Support Services
HIRDLS	High Resolution Dynamics Limb Sounder
HIWRAP	High-Altitude Imaging Wind and Rain Airborne Profiler
HOPE	Hyperspectral Ocean Phytoplankton Exploration
HS3	Hurricane and Severe Storm Sentinel
HSB	Humidity Sounder for Brazil
I3RC	Intercomparison of 3D Radiation Codes
IAMAS	International Association of Meteorology and Atmospheric Sciences
IASI	Infrared Atmospheric Sounding Interferometer
ICAP	International Cooperative for Aerosol Prediction
ICCARS	Investigating Climate Change and Remote Sensing
ICESat	Ice, Cloud, and land Elevation Satellite
IIP	Instrument Incubator Program
INPE	National Institute for Space Research (Brazil)
IPCC	Intergovernmental Panel on Climate Change
IPY	International Polar Year
IRAD	Internal Research and Development
IRC	International Radiation Commission
ITCZ	Intertropical Convergence Zone
IUGG	International Union of Geodesy and Geophysics

Acronyms

JAXA	Japanese Aerospace Exploration Agency
JCET	Joint Center for Earth Systems Technology
JPL	Jet Propulsion Laboratory
JPSS	Joint Polar Satellite System
JWST	James Webb Space Telescope
LaRC	Langley Research Center
LASP	Laboratory for Atmospheric and Space Physics
LDCM	Landsat Data Continuity Mission
LDSD	Low Density Sonic Decelerator program
LIS	Lightning Imaging Sensor
LIS	Land Information System
LPVEx	Light Precipitation Validation Experiment
LRRP	The Laser Risk Reduction Program
MABEL	Multiple Altimeter Beam Experimental Lidar
MAIAC	Multi-Angle Implementation of Atmospheric Correction
MC3E	Mid-latitude Continental Convective Clouds Experiment
MISR	Multi-angle Imaging Spectroradiometer
MJO	Madden-Julian Oscillation
MLS	Microwave Limb Sounder
MMF	Multi-scale Modeling Framework
MMF-LIS	Multi-scale Modeling Framework Land Information System
MODIS	Moderate Resolution Imaging Spectroradiometer
MoE	Ministry of Environment
MOHAVE	Measurement of Humidity in the Atmosphere and Validation Experiment
MOPITT	Measurement of Pollution in the Troposphere
MPLNET	Micro Pulse Lidar Network
MSU	Morgan State University
NCAR	National Center for Atmospheric Research
NCTAF	National Commission on Teaching and America's Future
NEO	NASA Earth Observations
NIST	National Institute of Standards
NISTAR	Advanced Radiometer
NLDAS-2	North American Land Data Assimilation System
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar Orbiting Environmental Satellite System
NPOL	Naval Physical and Oceanographic Laboratory
NPP	National Polar-orbiting Partnership

NRC	National Research Council
NRL	Naval Research Laboratory
NSF	National Science Foundation
NSIDC	National Snow and Ice Data Center
NSTA	National Science Teachers Association
OASIS	Ocean Ambient Sound Instrument System
OCO-2	Orbiting Carbon Observatory
ODSs	Ozone Depleting Substances
OEI	Ozone ENSO Index
OLI	Operational Land Imager
OMI	Ozone Monitoring Instrument
OMPS	Ozone Monitoring and Profiling Suite
OMPS	Ozone Mapping and Profiler Suite
PACE	Pre-Aerosols, Clouds, and Ecology
PI	Principal Investigator
PR	Precipitation Radar
PSCs	Polar Stratospheric Clouds
PUMAS	Practical Uses of Math and Science
PVI	Perpendicular Vegetation Index
RESA	Regional Education Service Agency
ROMS	Regional Ocean Modeling System
ROSES	Research Opportunities in Space and Earth Sciences
RSESTeP	Remote Sensing Earth Science Teacher Program
RSIF	Rain-Sea Interaction Facility
SAF	Satellite Application Facility
SAIC	Science Applications International Corporation
SDC	Science Director's Council
SEAC4RS	Southeast Asia Composition, Cloud, Climate Coupling Regional Study
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
SGP	South Great Plains
SHADOZ	Southern Hemisphere Additional Ozonesondes
S-HIS	Scanning High-Resolution Interferometer Sounder
SIM	Spectral Irradiance Monitor
SIMPL	Swath Imaging Multi-polarization Photon-counting Lidar
SMART	Surface-sensing Measurements for Atmospheric Radiative Transfer
SORCE	Solar Radiation and Climate Experiment
SPARRO	Self-Piloted Aircraft Rescuing Remotely Over Wilderness

Acronyms

SPE	Solar Proton Event
SSA	Single Scattering Albedo
SSAI	Science Systems Applications, Inc.
SSI	Solar Spectral Irradiance
SST	Sea Surface Temperature
STEM	Science, Technology, Engineering, and Mathematics
SWOT	Surface Water Ocean Topography
TES	Tropospheric Emission Spectrometer
TIM	Total Irradiance Monitor
TIROS	Television Infrared Observation Satellite Program
TIRS	Thermal Infrared Sensor
TJSTAR	Thomas Jefferson Symposium To Advance Research
TMI	TRMM Microwave Imager
TOGA	Tropical Ocean Global Atmosphere
TOMS	Total Ozone Mapping Spectrometer
TRMM	Tropical Rainfall Measurement Mission
TROPOMI	Troposhere Ozone Monitoring Instrument
TSI	Total Solar Irradiance
TSIS	Total Spectral Solar Irradiance Sensor
TWiLiTE	Tropospheric Wind Lidar Technology Experiment
UARS	Upper Atmosphere Research Satellite
UAVs	Unmanned Aerial Vehicles
UMBC	University of Maryland, Baltimore County
UMSA	Universidad Mayor San Andres
USGS	United States Geological Survey
USRA	Universities Space Research Associates
UTLS	Upper Troposphere and Lower Stratosphere
UV	Ultraviolet
VIIRS	Visible Infrared Imaging Radiometer Suite
VIRS	Visible and Infrared Scanner
WAVES	Water Vapor Validation Experiments Satellite and sondes
WFF	Wallops Flight Facility

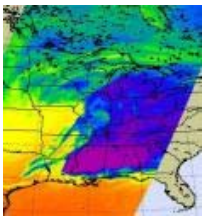
APPENDIX 1: ATMOSPHERIC SCIENCES IN THE NEWS

NASA and other satellites keeping busy with this week's severe weather

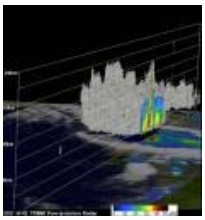
Published: Wednesday, March 9, 2011 - 14:37

Related images

NOAA/NASA GOES Project



NASA JPL, Ed Olsen



NASA/SSAI, Hal Pierce

Satellites have been busy this week covering severe weather across the U.S. Today, the GOES-13 satellite and NASA's Aqua satellite captured an image of the huge stretch of clouds associated with a huge and soggy cold front as it continues its slow march eastward. Earlier this week, NASA's Tropical Rainfall Measuring Mission

satellite captured images of severe weather that generated tornadoes over Louisiana. Today the eastern third of the U.S. is being buffered by a large storm that stretches from southeastern Minnesota east to Wisconsin and Michigan, then south through the Ohio Valley and all the way down to eastern Louisiana. That massive storm system was captured in an image by the Geostationary Operational Environmental Satellite called GOES-13.

GOES satellites are operated by the National Oceanic and Atmospheric Administration, and NASA's GOES Project, located at NASA's Goddard Space Flight Center, Greenbelt, Md. creates some of the GOES satellite images and animations.

Dennis Chesters, a GOES Project scientist at NASA Goddard, noted "The wide angle view provided by GOES reveals that the on-shore flow from the Gulf is part of a much larger oceanic circulation centered east of the Bahamas. That is driving a nearly unlimited supply of warm moisture over the eastern U.S. from as far south as Jamaica. With all that energy to work with, the wall of condensation and rainfall at the front pushed convective towers up to the stratosphere, which cast long shadows into the dawn behind the storm."

Flooding is already occurring in various areas around the eastern third of the U.S. NOAA's National Weather Service Hydrometeorological Prediction Center (HPC), the organization that monitors flooding, noted that flooding is already occurring in west-central Illinois, and along the Illinois/Kentucky border area of the Ohio River. Flooding has also been on-going this past week in Indiana. Heavy rains had previously flooded roads and raised levels of creeks and rivers across the state. This system is expected to bring up to a quarter of an inch more rain to the soggy state, maybe mixed with some snow near Indianapolis tonight. For more information about flooding maps and potential flood areas, go to the NOAA HPC website: http://www.hpc.ncep.noaa.gov/nationalfloodoutlook/index.html.

The storm is forecast by the National Weather Service (NWS) to move eastward by Thursday and affect the central Appalachian Mountains and U.S. east coast bringing heavy rainfall. The rainfall potentials will be high because the system is expected to pull moisture northward from the Gulf of Mexico up into the Ohio Valley. As the storm system progresses, more moisture will feed in from the Atlantic Ocean over the east coast.

NASA's Aqua satellite captured another view of the massive storm system today, March 9 at 07:59 UTC (2:59 a.m. EST) that revealed deep convection (rapidly rising air that forms thunderstorms) and cold cloud top temperatures in the southern part of the system.

Cloud temperatures are a key in determining storm strength. The higher the cloud tops are, the stronger the convection and the stronger the thunderstorms are. That's why infrared data from AIRS is so important to forecasters. AIRS data showed that most of the coldest, highest cloud tops and strongest thunderstorms (and heaviest rainfall) were over eastern Louisiana, Mississippi and Alabama this morning, and those cloud-tops were as cold as or colder than -63 Fahrenheit (-52 Celsius).

The northernmost part of the storm is expected to bring light snows, freezing rain and rain to some areas of the upper Midwest and east to northern New England on Thursday. Further south, light to moderate rains are expected over the Ohio and Tennessee Valleys today, that will move northeast tomorrow.

The New York metro area is expecting between 1 and 3 inches of rain as the front creeps eastward and a series of low pressure waves develop along it. Flooding of rivers, small streams and poorly drained areas will be possible. Further north in Albany, N.Y. snow is expected to mix into the rain.

In the Mid-Atlantic, heavy rains are possible from this slow moving low pressure area and associated cold front. The same area received heavy rain just four days before on Sunday. Today, the National Weather Service in Washington, D.C. has posted flood watches and coastal flood watches. The Nation's Capital may receive up to three inches of rain before the storm passes late Thursday. Farther south in Norfolk, Va. 1 to 2 inches of rainfall are expected, and south central and southeast Virginia along with northeast North Carolina may get strong to severe thunderstorms on Thursday.

The central Gulf coast and southeastern U.S. are expected to see showers and thunderstorms from the front, and there's a slight risk of severe thunderstorms in that region Wednesday and Thursday. The NWS in Savannah, Ga. forecast says "a few of the storms may become severe with damaging wind gusts and possibly isolated tornadoes between midnight tonight (Wednesday) and dawn on Thursday along and to the west of Interstate 95."

Farther south in Florida, Jacksonville is going to see an interaction of that approaching cold front with strong high pressure to the north that will kick up winds from the south to the southeast today, gusting to 35 mph, so a lake wind advisory was issued today from the local NWS. There's also a moderate risk of rip currents at the beaches. Even before the front gets there, a pre-frontal squall line is forecast to cross the Gulf Coast region today, and the NWS says there is a potential for strong or possibly severe thunderstorms to impact interior southeast Georgia and the northern Suwannee River Valley in Northeast Florida.

This past weekend, NASA's Tropical Rainfall Measuring Mission (TRMM) satellite was flying in space when it passed over tornadoes occurring in the state of Louisiana on March 5 at 1411 UTC (8:11 a.m. CST). The National Oceanic and Atmospheric Administration (NOAA) reported that seven tornadoes were spotted in Louisiana on that date. Those tornadoes caused at least 15 injuries and one death when a tornado hit in the northwest section of Rayne, Louisiana.

TRMM captured rainfall rates of the tornadic thunderstorms from March 5, 2011 when the system generated tornadoes in Louisiana. TRMM's Microwave Imager and Precipitation Radar showed that extremely heavy rainfall was falling from those storms at a rate of more than 2 inches (50 mm) per hour. Surrounding the intense rainfall areas were areas of moderate rainfall between .78 to 1.57 inches (20 to 4 mm) per hour.

Another view of the storm looking from the east was created by the TRMM Team at NASA Goddard. Using TRMM Precipitation Radar data, Hal Pierce of the NASA TRMM team created a 3-D image that sliced through the storm. The 3-D image showed that one of those powerful tornadic thunderstorms had intense echoes reaching as high as 9.3 miles (15km).

TRMM images are pretty complicated to create. At NASA Goddard, rain rate data from the TRMM Precipitation Radar (PR) instrument are taken from the center of the swath (the satellite's orbit path over the storm). The rain rates in the outer portion of the storm are created from a different instrument on the satellite, called the TRMM Microwave Imager (TMI). The rain rates are then overlaid on infrared (IR) data from the TRMM Visible Infrared Scanner (VIRS). The TRMM satellite is managed by NASA and the Japanese Space Agency, JAXA. For more information about TRMM, visit: http://www.trmm.gsfc.nasa.gov/.

The GOES-13 satellite continues to provide updated imagery on the NASA GOES Project website at http://goes.gsfc.nasa.gov/, so if you want to see when sunshine and a clear sky will return, look to the left (west) of the cloud cover on GOES images.

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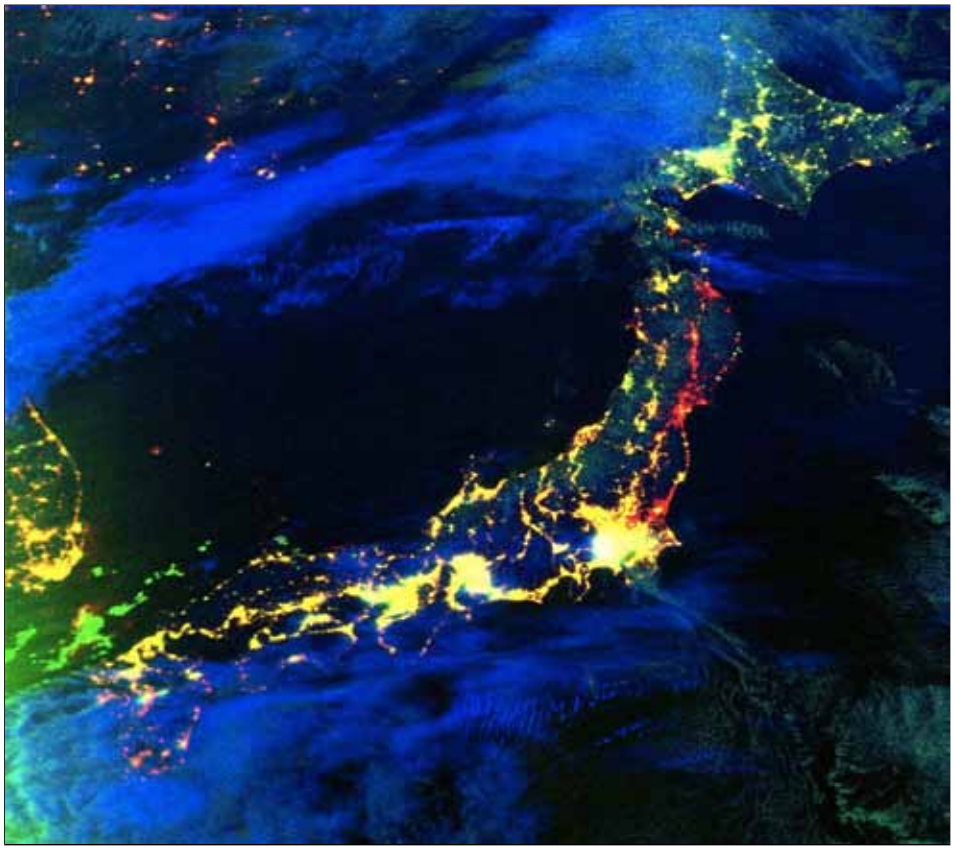
Tsunami Hits Home for Goddard Scientist

Posted on Mar 24, 2011 04:20:18 PM | Adam Voiland | 2 Comments |



On March 11, Teppei Yasunari, 31, a visiting scientist at Goddard Space Flight Center, heard that a massive earthquake off the coast of Japan had rocked his homeland and unleashed a deadly tsunami. For Yasunari, an atmospheric scientist who studies the climate effects of tiny airborne particles called aerosols, the frantic days that followed have offered powerful lessons

in both patience and science communication as Yasunari grappled with the news that one of his best friends was missing and that a nuclear plant in Fukushima prefecture seemed poised to send a plume of radioactive steam aloft. We sat down with Yasunari to hear his perspective on the disaster.

WoE: You are both an Earth scientist and Japanese. What went through your mind when you heard about the tsunami?

Yasunari: Like everybody, I was shocked. There are no words to describe it. It was hard to believe the video clips I was seeing on the web.

WoE: I know you grew up in Kyoto and Tsukuba, but have you spent any time in Sendai?

Yasunari: Some. I went to undergraduate college in Aomori prefecture, which is not so far from Sendai. I have visited friends who live in Sendai a number of times.

WoE: Were your friends from college ok?

Yasunari: One of the first things I did after I heard the news was try to contact one of my best friends from Hirosaki University who now lives in Iwate prefecture, which is just immediately north of Miyagi prefecture, the prefecture the earthquake hit the hardest. I tried emailing and calling, but I couldn't get through. All lines of communication were down. I tried calling friends of friends. Nothing worked. Finally, I registered his name in Google Person Finder.

WoE: How long were you in limbo?

Yasunari: About three days. Finally, I saw something on Person Finder that said he was probably ok. A friend of his from grade school had heard from somebody else that a firefighter had found him. I later heard through Person Finder that he'd been moved to someone's home, but I still haven't been able to email or call him. On March 22, I did get an e-mail directly from him. He said his house has been completely destroyed by the tsunami. It was such a relief to have finally heard from him directly.

WoE: I imagine you must have been glued to the Internet looking for information.

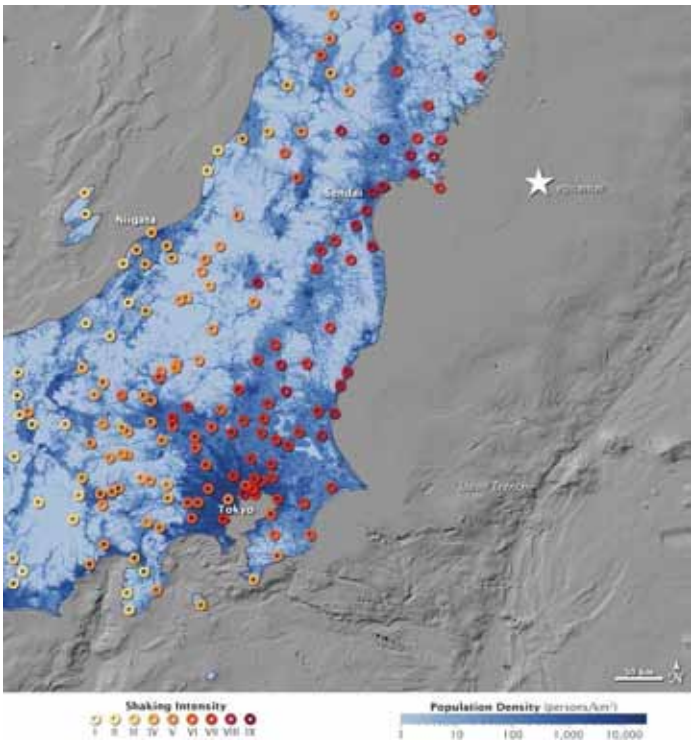
Yasunari: Yes, especially Twitter, Facebook, and Japanese SNS. Since the phone and power is out in some parts of Japan, these sites are often the quickest way to get information. My personal Twitter feed is @TJ_Yasbee.

WoE: Did you look to Twitter for scientific information about what was going on with the earthquake and nuclear plant?

Yasunari: Yes. Actually something surprising happened on Twitter. Since I have studied the long range transport of aerosols, I calculated some air mass transport patterns using the NOAA atmospheric dispersion model called HYSPLIT when I heard about the possibility of a

radioactive plume, I wanted to help, so I made some simple figures that showed what direction, based on the model, a plume might move.

WoE: And you tweeted the figures?



Yasunari: Yes. I only had less than 300 followers at that point. However, a physicist from the University of Tokyo, Ryugo Hayano, saw the figures and contacted me by email. He ended up tweeting his comments with my figure to his more than 40,000 followers. Neither of us could have imagined how quickly that tweet spread. It wasn't long before newspapers were contacting me to use the figures. I couldn't believe it.

WoE: Forty-thousand followers is quite a lot for a scientist.

Yasunari: He is well known. He tweets from @hayano. Now he has more than 150,000 followers in just a couple of days because of the earthquake.

WoE: Did you see a surge of followers on Twitter as well?

Yasunari: Yes, originally I had about 300. Now I have more than 2,100.

WoE: How did people react to the figures?

Yasunari: The model I made the figures with has quite a coarse resolution, and it can't show any more than a broad view of how a plume might move. But people in Japan are so worried about the threat of radiation and eager for information that some of them treated it like it was very fine resolution and accurate.

WoE: So did the newspapers end up using the figure?

Yasunari: In the end, in consultation with a scientist from NOAA, we decided that it would

be more confusing than helpful for the public. We asked the newspapers not to use them, and I took them down from Twitter. I learned a lot from this.

WoE: You can't really delete a tweet, though, can you?

Yasunari: No, but I had tweeted it through Twitpics, and professor Hayano had use a similar site called Plixi, so we were able to take the figures down.

WoE: It certainly raises interesting questions about social media and science communication. Do you wish you had never tweeted the figure in the first place?

Yasunari: Yes and no. The tweet was intended just for my small number of followers, but I never realized how quickly it would spread. Of course, I expected it would spread some, but I didn't expect it to go viral. In the future, I will be much more aware that the public doesn't pay much attention to the uncertainties when I show a figure.

At the same time, I wish they would. Twitter and other social media can be a very convenient way for scientists to communicate, so I don't want to say that scientists should never use social media or have a blog. I guess the best thing to do is try to find a balance between showing too much information and too little.

WoE: What about your family? Were they affected by the earthquake?

Yasunari: I contacted my family immediately after the earthquake. They were fine because they live in a western part of Japan, about 500 miles away from Sendai. We were extremely lucky. My father, also a scientist, was supposed to be in Sendai on business the day of the earthquake. Fortunately, he canceled the trip the day before he was suppose to leave because he was busy with other things.

WoE: How lucky. Does your father also study aerosols and climate?

Yasunari: No, but he is also an atmospheric scientist. He focuses on meteorology and climatology related to Asian monsoons. In fact, he has collaborated with Bill Lau, the chief of the branch I'm in at Goddard. Both Bill Lau and my father are examining the idea that aerosols can have an important impact on the monsoons -- a hypothesis called the "elevated heat pump."

WoE: Is that a topic that you study as well?

Yasunari: In some ways, yes. I recently published a paper that will help quantify how much black carbon and dust are affecting the rate of Himalayan glacier retreat. Another study, led by a scientist from the Pacific Northwest National Laboratory, cited both my paper and my father's paper at the same time. It was the first time double Yasunari reference in the same paper.

WoE: Thanks for talking to us, and best of luck to your friend.

Yasunari: You're welcome. I know Japan will overcome this difficult situation.

Top Image: A United States Air Force satellite observed the widespread loss of electricity in parts of northeastern Japan after the earthquake. The

image, a composite, shows functioning electricity from 2010 and 2011. Red indicates power outages detected on March 12, 2011, compared to data from 2010. For more information about the map, please visit this page. Credit: NASA Earth Observatory/NOAA National Geophysical Data Center.

Middle Image: Teppei Yasunari in his office. Credit: NASA/Adam Voiland

Lower Image: A shaking intensity map based on USGS data shows ground motion at multiple locations across Japan during the earthquake. A shaking intensity of VI is considered "strong" and can produce "light damage," while a IX on the scale is described as "violent" and likely to produce "heavy damage. For more information about the map, please visit this page. Credit: NASA Earth Observatory/Rob Simmon & Jesse Allen

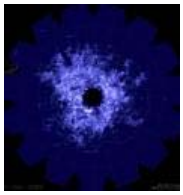
--Adam Voiland, NASA's Earth Science News Team

e! Science News

Clouds, clouds, burning bright

Published: Tuesday, April 19, 2011 - 08:37

Related images



NASA/HU/VT/CU LASP

High up in the sky near the poles some 50 miles above the ground, silvery blue clouds sometimes appear, shining brightly in the night. First noticed in 1885, these clouds are known as noctilucent, or "night shining," clouds. Their discovery spawned over a century of research into what conditions causes them to form and vary – questions that still tantalize scientists to this day. Since 2007, a NASA mission called Aeronomy of Ice in the Mesosphere (AIM) has shown that the cloud formation is changing year to year, a process they believe is intimately tied to the weather and climate of the whole globe. "The formation of the clouds requires both water and incredibly low temperatures," says Charles Jackman, an atmospheric scientist at NASA's Goddard Space Flight Center in Greenbelt, Md., who is NASA's project scientist for AIM. "The temperatures turn out to be one of the prime driving factors for when the clouds appear."

So the appearance of the noctilucent clouds, also known as polar mesospheric clouds or PMCs since they occur in a layer of the atmosphere called the mesosphere, can provide information about the temperature and other characteristics of the atmosphere. This in turn, helps researchers understand more about Earth's low altitude weather systems, and they've discovered that events in one hemisphere can have a sizable effect in another.

Since these mysterious clouds were first spotted, researchers have learned much about them. They light up because they're so high that they reflect sunlight from over the horizon. They are formed of ice water crystals most likely created on meteoric dust. And they are exclusively a summertime phenomenon.

"The question people usually ask is why do clouds which require such cold temperatures form in the summer?" says James Russell, an atmospheric scientist at Hampton University in Hampton, Va., who is the Principal Investigator for AIM. "It's because of the dynamics of the atmosphere. You actually get the coldest temperatures of the year near the poles in summer at that height in the mesosphere."

As summer warmth heats up air near the ground, the air rises. As it rises, it also expands since atmospheric pressure decreases with height. Scientists have long known that such expansion cools things down – just think of how the spray out of an aerosol can feels cold – and this, coupled with dynamics in the atmosphere that drives the cold air even higher, brings temperatures in the mesosphere down past a freezing -210º F (-134 ºC).

In the Northern hemisphere, the mesosphere reaches these temperatures consistently by the middle of May. Since AIM has been collecting data, the onset of the Northern season has never varied by more than a week or so. But the southern hemisphere turns out to be highly variable. Indeed, the 2010 season started nearly a month later than the 2009 season.

Atmospheric scientist Bodil Karlsson, a member of the AIM team, has been analyzing why the start of the southern noctilucent cloud season can vary so dramatically. Karlsson is a researcher at Stockholm University in Sweden, though until recently she worked as a post-doctoral researcher at the University of Colorado. A change in when some pretty clouds show up may not seem like much all by itself, but it's a tool for mapping the goings-on in the atmosphere, says Karlsson.

"Since the clouds are so sensitive to the atmospheric temperatures," says Karlsson. "They can act as a proxy for information about the wind circulation that causes these temperatures. They can tell us that the circulation exists first of all, and tell us something about the strength of the circulation."

She says the onset of the clouds is timed to something called the southern stratospheric vortex – a winter wind pattern that circles above the pole. In 2010, that vortex lingered well into the southern summer season, keeping the lower air cold and interfering with cloud formation. This part of the equation is fairly straightforward and Karlsson has recently submitted a paper on the subject to the Journal of Geophysical Research. But this is not yet the complete answer to what drives the appearance of these brightly lit clouds.

AIM researchers also believe there is a connection between seemingly disparate atmospheric patterns in the north and south. The upwelling of polar air each summer that contributes to noctilucent cloud formation is part of a larger circulation loop that travels between the two poles. So wind activity some 13,000 miles (20,920 km) away in the northern hemisphere appears to be influencing the southern circulation.

The first hints that wind in the north and south poles were coupled came in 2002 and 2003 when researchers noticed that despite a very calm lower weather system near the southern poles in the summer, the higher altitudes showed variability. Something else must be driving that change.

Now, AIM's detailed images of the clouds have enabled researchers to look at even day-to-day variability. They've spotted a 3 to10 day time lag between low-lying weather events in the north – an area that, since it is fairly mountainous, is prone to more complex wind patterns – and weather events in the mesosphere in the south. On the flip side, the lower atmosphere at the southern poles has little variability, and so the upper atmosphere where the clouds form at the northern poles stays fairly constant. Thus, there's a consistent start to the cloud season each year.

"The real importance of all of that," says Hampton's Russell, "is not only that events down where we live can affect the clouds 50 miles (80 km) above, but that the total atmosphere from one pole to the next is rather tightly connected."

Hammering out the exact mechanisms of that connection will, of course, take more analysis. The noctilucent cloud season will also surely be affected by the change in heat output from the sun during the upcoming solar maximum. Researchers hope to use the clouds to understand how the sun's cycle affects the Earth's atmosphere and the interaction between natural- and humankind-caused changes.

"These are the highest clouds in Earth's atmosphere, formed in the coldest place in Earth's atmosphere," says Goddard's Jackman. "Although the clouds occur only in the polar summer, they help us to understand more about the whole globe."

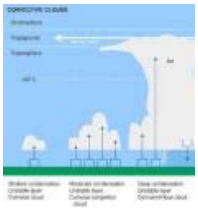
Source: NASA/Goddard Space Flight Center

e! Science News

NASA mission seeks to uncover a rainfall mystery

Published: Wednesday, April 27, 2011 - 12:33

Related images



NASA Langley

NASA Dryden

Scientists from NASA and other organizations are on a mission to unlock the mysteries of why certain clouds produce copious amounts of rain. In a field mission that is now under way, aircraft are carrying instruments above and into rain clouds. Meanwhile scientists are also getting rainfall measurements on the ground. This field campaign provides the most comprehensive observations of rainfall in the U.S. through the use of aircraft, spacecraft, remote sensing and ground sensors.

Convective clouds are the focus of a NASA mission that runs from April to June, 2011. Convective clouds form when warm, moist air rises and condenses at higher altitudes. Cumulus and cumulonimbus clouds or thunderclouds are types of convective clouds.

On April 22, scientists from NASA and the U.S. Department of Energy (DOE) launched a weeks-long field campaign to learn more about the inner workings of cloud systems that generate significant amounts of rainfall. The field campaign, called the Mid-latitude Continental Convective Clouds Experiment (MC3E), will run until June 6 from the DOE's Southern Great Plains site near Ponca City in central Oklahoma. Because April through June is severe weather season in Oklahoma, there will be plenty of convective clouds to study.

"Because precipitation is so critical to our daily existence, we naturally would like to know how much rain falls at any given place and time," said Walt Petersen, a scientist at the NASA Marshall Space Flight Center in Huntsville, Ala., who is leading NASA's component of the campaign. "Our goal is to observe and measure the entire precipitation process, from the ice that forms near the tops of clouds to the rainfall that ends up on the ground."

types, and shapes of precipitation from aircraft flying at lower altitudes within the cloud. Meanwhile, ground-based radars and imaging networks are analyzing the precipitation that actually falls to the ground.

Data from various satellites are also being used in MC3E. NASA's CloudSat, CALIPSO, Aqua, and Tropical Rainfall Measuring Mission (TRMM) satellites are also providing data to the field campaign. NOAA is providing data from their GOES and polar orbiting satellites.

The goal of MC3E is to intensively sample the entire column of the atmosphere underneath the satellite simulator (the ER-2) and verify that all aircraft and ground-based measurements paint a consistent picture of precipitation physics, Petersen said.

Convective clouds are most common in the tropics. Convective cloud systems are also common at higher latitudes, including Oklahoma, and appear as puffs, mounds, or towering clouds that can range from as low as 1,000 feet to more than 50,000 feet. In these clouds, large amounts of water vapor are cooled and condensed into water droplets and eventually falls as precipitation.

"Convective cloud processes play a critical role in our daily lives," added Michael Jensen, the meteorologist leading the DOE element of the MC3E campaign. "To represent these cloud systems in computer models of the atmosphere, we need to understand the details of why these clouds form, where they form, how they grow and shrink, and what factors control the amount of rain that falls from them. MC3E will provide insights into all of these questions."

Scientists will use this data to advance techniques for deriving more accurate rainfall information from a network of satellites as part of the Global Precipitation Measurement (GPM) mission satellite to be launched in 2013. GPM, an international partnership lead by NASA and the Japanese Aerospace Exploration Agency (JAXA) in coordination with space agencies of many nations, will measure rain and snow over the entire globe using more sophisticated instruments. It builds on the success of the NASA-JAXA TRMM satellite, which provides scientists with daily worldwide rain intensities in the tropics.

"Our ability to relate satellite observations to rain that hits the ground requires detailed knowledge of the atmospheric column above it," says Arthur Hou, the GPM project scientist at the NASA Goddard Space Flight Center in Greenbelt, Md. "That is why data collected in field campaigns like MC3E are vital for refining satellite algorithms during the pre-launch phase."

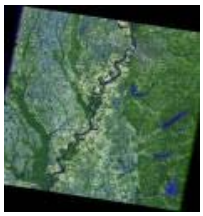
"The end goal of this campaign is to collect a dataset that enables us to build the best set of methods to estimate the amount of precipitation over a point on the earth's surface from an orbiting GPM satellite," Petersen explained. This will improve the accuracy of future satellite instruments, including those flying on GPM.

Source: NASA/Goddard Space Flight Center

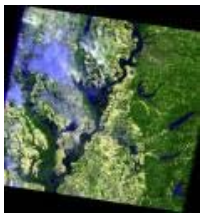
Satellite images display extreme Mississippi River flooding from space

Published: Friday, May 13, 2011 - 16:03

Related images



USGS/NASA



USGS/NASA

Recent Landsat satellite data captured by the USGS and NASA on May 10 shows the major flooding of the Mississippi River around Memphis, Tenn. and along the state borders of Tennessee, Kentucky, Missouri, and Arkansas as seen from 438 miles above the Earth. The flood crest of 47.87 feet on May 10, is the second highest rise in recent history; the highest being 48.7 feet in 1937. Five counties surrounding Memphis have been declared disaster areas, and the costs of the flooding are expected to approach $1 billion. The Mississippi River crest continues to move south and is expected to occur in the Greenville, Miss. Area around May 16 to finally crest in New Orleans around May 23.

When natural hazards like flooding occur, USGS provides the most recent Landsat data to local emergency managers.

"Landsat imagery is crucial in helping to monitor the flood rate and effects of the flooding in the region, and to aid in the decision making process regarding flood control. Decisions such as closing portions of the Mississippi River

James Irons, Landsat Data Continuity Mission (LDCM) Project Scientist at NASA Goddard Space Flight Center in Greenbelt, Md. said, "NASA Goddard has managed the development of all the successfully launched Landsat satellites and is currently developing the next Landsat satellite system, the Landsat Data Continuity Mission, in partnership with USGS." The launch of LDCM is scheduled for December, 2012.

Remotely sensed data are not the only science endeavors occurring due to floods. The USGS collects river data through its network of about 7,700 stream gauges around the Nation. You can receive instant, customized updates about water conditions, including flooding, by subscribing to USGS WaterAlert (› http://water.usgs.gov/wateralert).

General flood information is available at USGS Science Features () and USGS Flood Information (› http://water.usgs.gov/osw/floods/).

The scenes captured by Landsat 5 show the Mississippi River in the Memphis, Tenn. area, and along the state borders of Tennessee, Kentucky, Missouri, and Arkansas. The January images show the river before it began to flood. In the May images, the dark blue tones are water, the light green is cleared fields, and the light tones are clouds.

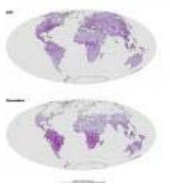
Source: NASA/Goddard Space Flight Center

e! Science News

First-of-its-kind fluorescence map offers a new view of the world's land plants

Published: Monday, June 6, 2011 - 18:34

Related images



NASA's Earth Observatory

Scientists from NASA's Goddard Space Flight Center in Greenbelt, Md., have produced groundbreaking global maps of land plant fluorescence, a difficult-to-detect reddish glow that leaves emit as a byproduct of photosynthesis. While researchers have previously mapped how ocean-dwelling phytoplankton fluoresce, the new maps are the first to focus on land vegetation and to cover the entire globe. To date, most satellite-derived information related to the health of vegetation has come from "greenness" indicators based on reflected rather than fluorescent light. Greenness typically decreases in the wake of droughts, frosts, or other events that limit photosynthesis and cause green leaves to die and change color.

However, there is a lag between what happens on the ground and what satellites can detect. It can take days --- even weeks -- before changes in greenness are apparent to satellites.

Chlorophyll fluorescence offers a more direct window into the inner workings of the photosynthetic machinery of plants from space. "With chlorophyll fluorescence, we should be able to tell immediately if plants are under environmental stress -- before outward signs of browning or yellowing of leaves become visible," said Elizabeth Middleton, a NASA Goddard-based biologist and a member of the team that created the maps.

The new maps, based on data collected in 2009 from a spectrometer aboard a Japanese satellite called the Greenhouse Gases Observing Satellite (GOSAT), show sharp contrasts in plant fluorescence between seasons. In the Northern Hemisphere, for example, fluorescence production peaked during July, while in the Southern Hemisphere it did in December.

The new findings help confirm previous lab and field experiments that suggest chlorophyll fluorescence should

taper off in the fall as the abundance of green foliage declines and stress increases as a result of lower temperatures and less favorable light conditions.

While additional research is required to sort out the subtleties of the fluorescence signal, the new maps are significant as they demonstrate the feasibility of measuring fluorescence from space.

In the future, the Goddard team expects that fluorescence measurements will complement existing measures of "greenness" in a variety of ways. They could help farmers respond to extreme weather or make it easier for aid workers to detect and respond to famines. Fluorescence could also lead to breakthroughs in scientists' understanding of how carbon cycles through ecosystems – -- one of the key areas of uncertainty in climate science.

"What's exciting about this is that we've proven the concept," said Joanna Joiner, the deputy project scientist for NASA's Aura mission and the leader of the Goddard team that created the maps. "The specific applications will come later."

Glowing Plants?

The same mechanism that makes plants fluoresce causes a range of everyday objects -- ground-up plant leaves, white shirts, jellyfish, and even blood and urine -- to glow intensely under black light.

However, plants fluoresce in specific parts of the blue, green, red, and far-red spectrum. Chlorophyll fluorescence from green foliage, for example, is produced at the red and far-red wavelengths.

"In plants, fluorescence is not something that you can see with your naked eye because background light overwhelms it," explained Joiner, the lead author of the paper. When sunlight strikes a leaf, disc-like green structures called chloroplasts absorb most of the light and convert it into carbohydrates through photosynthesis.

Chloroplasts re-emit about two percent of incoming light at longer, redder wavelengths. This re-emitted light -- fluorescent light -- is what the Goddard scientists measured to create their map. Fluorescence is different than bioluminescence, the chemically-driven mechanism lightning bugs and many marine species use to glow without exposure to light.

For decades, scientists have measured fluorescence in plants by exposing leaves to laser beams that, like black light, make fluorescence more apparent. Such experiments have revealed much about how certain types of plants fluoresce, but researchers have not been able to use lasers to measure the phenomenon across broad swaths of the Earth's surface.

To create their global fluorescence map, Joiner and her colleagues used a different technique. They analyzed an unusually dark section of the infrared portion of the solar spectrum embedded within a feature called a "Fraunhofer line." There is little background light at the line they focused on -- at about 770 nanometers -- which made it possible to distinguish the faint fluorescence signal.

The Future of Fluorescence

The new findings have implications for both current and upcoming satellite missions. In the near term, awareness

of the fluorescence signal should help atmospheric scientists refine measurements of carbon dioxide and methane from the GOSAT mission.

The creation of the maps also bolsters the argument that an experimental mission being developed by the European Space Agency (ESA) -- the Fluorescence Explorer (FLEX) mission -- would make significant breakthroughs. The ESA is currently in the midst of feasibility studies and has not yet set a launch date for FLEX.

The findings also suggest that NASA's Orbiting Carbon Observatory-2 (OCO-2), a mission that is designed to measure carbon dioxide levels much like GOSAT, should be able to make useful fluorescence measurements on a global scale. OCO 2 will launch no earlier than February of 2013 from Vandenberg Air Force Base in California.

The maps, published online in the journal Biogeosciences, represent just a first attempt to detect terrestrial fluorescence on a broad scale and will be enhanced and expanded over time, the scientists involved in the project emphasized.

More work needs to be done, for example, to understand how plant fluorescence varies depending on light conditions. In strong afternoon light, the conditions that GOSAT made its observations, unstressed plants produce a stronger fluorescence signal than stressed plants. However, complicating matters, the reverse is true in the morning or evening when light is less intense.

To disentangle the two opposing effects, the Goddard-based group plans to continue refining the mathematical methods they used to calculate fluorescence. Meanwhile, groups of scientists at NASA's Jet Propulsion Laboratory in Pasadena, Calif. -- as well as Japanese and European research groups -- are in the process of honing similar fluorescence-monitoring methods.

Source: NASA/Goddard Space Flight Center

GOES satellites see ash still spewing from Chilean volcano

Published: Wednesday, June 29, 2011 - 21:32

Related images

(Credit: NASA/NOAA GOES Project, Dennis Chesters)

Cordón volcano in Chile continues to spew ash that is still disrupting travel as far as Australia and New Zealand this week. A new animation of satellite imagery just released from the NASA/NOAA GOES Project shows the ash spewing from the volcano. Satellite data from the Geostationary Operational Environmental Satellites called GOES-13 and GOES-11, both managed by NOAA, have been providing images of the volcanic plume since the eruption began on June 4, 2011. Those images were created at NASA's GOES Project located at NASA's Goddard Space Flight Center, Greenbelt, Md. The images were compiled into an animation and sped up to show several days worth of eruptions in less than a minute.

The animation begins on June 24 at 0039 UTC (June 23 8:39 p.m. EDT) and runs 22 seconds. In the animation, the ash plume originally appears very thin as it blows northward. As the time series continues, the plume thickens and blows to the northwest into the Pacific Ocean. The animation ends on June 26 at 23:45 UTC (7:35 p.m. EDT).

Dennis Chesters of the NASA GOES Project noted of the animation, "The Chilean caldera still emits a steady stream of ash, three weeks after the initial eruption. Fortunately, the volume is much less, and the cold winter wind from the south carries it up the coast out over the Pacific, instead of over the Andes into Argentina."

According to CNN on June 28, the volcanic ash cloud was still affecting air travel in New Zealand, Australia. The eruptions of the Puyehue volcano, located in Puyehue National Park in the Andes of Ranco Province of Chile have also caused flight delays and cancellations in Argentina, Brazil, Chile and Uruguay.

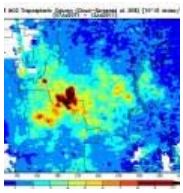
Source: NASA/Goddard Space Flight Center

e! Science News

NASA's Aura satellite measures pollution 'butterfly' from fires in central Africa

Published: Friday, July 15, 2011 - 16:02

Related images



NASA/James Acker

Fires raging in central Africa are generating a high amount of pollution that is showing up in data from NASA's Aura Satellite, with the ominous shape of a dark red butterfly in the skies over southern part of the Democratic Republic of the Congo and northern Angola. An image of the pollution from agricultural fires in central Africa was created from data of nitrogen dioxide (NO2) levels over the period from July 7 to 12, 2011. It was created from Ozone Measuring Instrument (OMI) data using the NASA Giovanni system by Dr. James Acker at NASA's Goddard Space Flight Center in Greenbelt, Md.

Each year, people in the region burn croplands to clear fields after harvests. Burning is also used to create new growth in pastures and move grazing animals to new locations.

NO2 forms during fires when nitrogen reacts with oxygen. In fact, NO2 is formed in any combustion process where the oxygen is provided by Earth's atmosphere.

Detection of NO2 is important because it reacts with sunlight to create low-level ozone or smog and poor air quality. The OMI instrument that flies aboard NASA's Aura satellite is able to detect NO2. Low-level ozone (smog) is hazardous to the health of both plants and animals, and ozone in association with particulate matter causes respiratory problems in humans.

OMI measures NO2 by the number of molecules in a cubic centimeter. The highest concentrations appear in dark red and are coming from extreme northern Angola and south central part of the Democratic Republic of the Congo. The high concentration coming from the DRC appears to look like a butterfly.

OMI data is archived at the NASA Goddard Earth Sciences Data and Information Services Center (GES DISC), and is provided by KNMI, the Koninklijk Nederlands Meteorologisch Instituut (Royal Netherlands Meteorological Institute). Dr. P.F. Levelt is the Principal Investigator of OMI, Dr. J. Tamminen is the Finnish Co-PI, and Dr. P.K. Bhartia leads the U.S. OMI science team. Dr. James Gleason (NASA) and Pepijn Veefkind (KNMI) are PIs of the OMI NO2 product.

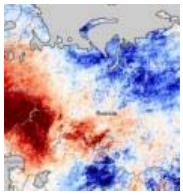
Source: NASA/Goddard Space Flight Center

e! Science News

Extreme 2010 Russian fires and Pakistan floods linked meteorologically

Published: Wednesday, August 31, 2011 - 21:38

Related images



Credit: NASA/Earth Observatory

Two of the most destructive natural disasters of 2010 were closely linked by a single meteorological event, even though they occurred 1,500 miles (2,414 km) apart and were of completely different natures, a new NASA study suggests. The research finds that the same large-scale meteorological event -- an abnormal Rossby wave -- sparked extreme heat and persistent wildfires in Russia as well as unusual downstream wind patterns that shifted rainfall in the Indian monsoon region and fueled heavy flooding in Pakistan. Although the heat wave started before the floods, both events attained maximum strength at approximately the same time, the researchers found by analyzing satellite data generated by NASA instruments capable of measuring the land surface temperature, precipitation intensity and wildfire activity.

William Lau and Kyu-Myong Kim, atmospheric scientists at NASA's Goddard Space Flight Center in Greenbelt, Md., authored the study, which the *Journal of Hydrometeorology* published in August.

A Rossby Connection

The atmosphere, gaseous and transparent, may not seem like a fluid, but that's precisely how the thin layer of air encasing the planet behaves. As Earth spins on its axis, huge rivers of air -- scientists call them Rossby waves -- meander around the globe in a westerly direction. Currents in the center of these waves form the jet streams, fast-moving columns of air that push weather systems from west to east.

Rossby waves aren't uniform. They tend to undulate and have troughs and ridges. Areas of low-pressure typically develop in the troughs of the waves, while high-pressure areas form in their ridges. Parcels of warm air from the tropics and cool air from the poles swirl around the low- and high-pressure parts of the waves creating a complex

tapestry of warm and cool fronts that meet and interact constantly. Collisions between warm and cool fronts produce storms and precipitation.

Under normal summertime conditions, the jet stream pushes weather fronts through Eurasia in four or five days, but something unusual happened in July of 2010. A large-scale, stagnant weather pattern -- known as an Omega blocking event -- developed over a high-pressure ridge above western Russia. This blocking event, which divided the jet stream, had the effect of slowing the Rossby wave and prevented the normal progression of weather systems from west to east.

As a result, a large region of high pressure formed over Russia and trapped a hot, dry air mass. As the high lingered, the land surface dried and the normal transfer of moisture from the soil to the atmosphere slowed. Precipitation ceased, vegetation dried out, and the region became a taiga tinderbox.

Meanwhile, the blocking pattern created unusual downstream wind patterns over Pakistan. Areas of low pressure on the leading edge of the Rossby wave formed in response to the high that pulled cold, dry Siberian air into lower latitudes.

"From NASA satellite data and wind analysis, we can clearly see the connection between the two events," Lau said. "Think of the atmosphere like a loose membrane. If you push one part up, something else has to come down somewhere else. If you produce a high in one region, you produce a corresponding low in another."

This cold air from Siberia clashed with warm, moist air arriving over Pakistan from the Bay of Bengal. There's nothing unusual about moisture moving north over India toward the Himalayas. It's a normal part of the monsoon. However, in this case, the unusual wind patterns associated with the blocking high brought upper level air disturbances farther south than is typical, which helped shift the entire monsoon rainfall system north and west. The shift brought heavy monsoon rains squarely over the northern part of Pakistan.

Future Directions

While the new study highlights the degree of interconnection that can exist between two seemingly unrelated weather events, Lau cautions that many questions remain. For example, why did such a powerful blocking high form in the first place? And did some particular process occurring on the land or in the atmosphere sustain and strengthen it?

Lau's analysis of data from the Modern Era Retrospective-analysis for Research and Applications (MERRA) -- an atmospheric model focused on hydrology that blends data from satellites and the Goddard Earth Observing System Model, Version 5 (GEOS-5) -- suggests that certain interactions between the land and atmosphere may have amplified the heat wave as it dragged on creating what climatologists call a positive feedback cycle.

Clouds, for example, typically provide shade and precipitation, but Lau's research shows they were suppressed in the vicinity of the blocking high because prolonged drought dried the soil and slowed the rate of evaporation. The modeling and satellite data suggest that over time the reduced cloud cover would have resulted in an even greater dose of heat reaching the surface, which, in turn, would have dried the soil out even more and amplified the effect.

What's more, Lau thinks that graphite-like dark particles in wildfire smoke -- a type of aerosol called black carbon -

Appendix 1: Atmospheric Sciences in the News

APPENDIX 2. REFEREED ARTICLES

Laboratory members' names are in boldface.

Allen, D.J., C.P. Loughner, **K.E. Pickering**, and R.R. Dickerson (2011). Characterization of an eastern US severe air pollution episode using WRF/Chem. *J. Geophys. Res.*, *116*(D17306). doi:10.1029/2010JD015054

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Appendix 2: Refereed Articles

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Appendix 2: Referreed Articles

APPENDIX 3. HIGHLIGHTED ARTICLES PUBLISHED IN 2011

A Study on the Feasibility of Dual-Wavelength Radar for Identification of Hydrometeor Phases

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(Manuscript received 25 February 2010, in final form 3 September 2010)

ABSTRACT

An important objective for the dual-wavelength Ku-/Ka-band precipitation radar (DPR) that will be on board the Global Precipitation Measurement (GPM) core satellite is to identify the phase state of hydrometeors along the range direction. To assess this, radar signatures are simulated in snow and rain to explore the relation between the differential frequency ratio (DFR), defined as the difference of radar reflectivity factors between Ku and Ka bands, and the radar reflectivity factor at Ku band Z_{Ku} for different hydrometeor types. Model simulations indicate that there is clear separation between snow and rain in the Z_{Ku}–DFR plane assuming that the snow follows the Gunn–Marshall size distribution and rain follows the Marshall–Palmer size distribution. In an effort to verify the simulated results, the data collected by the Airborne Second-Generation Precipitation Radar (APR-2) in the Wakasa Bay Advanced Microwave Scanning Radiometer for Earth Observing System (AMSR-E) campaign are employed. Using the signatures of linear depolarization ratio at Ku band, the APR-2 data can be easily divided into the regions of snow, mixed phase, and rain for stratiform storms. These results are then superimposed onto the theoretical curves computed from the model in the Z_{Ku}–DFR plane. For over 90% of the observations from a cold-season stratiform precipitation event, snow and rain can be distinguished if the Ku-band radar reflectivity exceeds 18 dBZ (the minimum detectable level of the GPM DPR at Ku band). This is also the case for snow and mixed-phase hydrometeors. Although snow can be easily distinguished from rain and melting hydrometeors by using Ku- and Ka-band radar, the rain and mixed-phase particles are not always separable. It is concluded that Ku- and Ka-band dual-wavelength radar might provide a potential means to identify the phase state of hydrometeors.

1. Introduction

The Global Precipitation Measurement (GPM) mission has been proposed for mapping of precipitation globally following the success of the Tropical Rainfall Measuring Mission, which measures the precipitation in tropical and subtropical regions (Simpson et al. 1996; Kummerow et al. 2000; Kozu et al. 2001). The dual-wavelength precipitation radar (DPR) on board the GPM core satellite is expected to improve the accuracy of estimates of precipitation rate and also to enable the retrieval of microphysical properties of hydrometeors, such as particle size distribution and phase state. Because the GPM will fly in a higher orbital inclination (65°), the radar observations will be extended to mid- and high-latitude regions where both snow and rain frequently occur. Moreover, because the radar algorithms for estimates of precipitation rate and water content differ for snow and rain, it is necessary to study the feasibility of the GPM DPR for identification of hydrometeor phase state. This capability is also useful in convective rain where a clearly defined bright band is usually absent. Having knowledge of where regions of snow, rain and mixed-phase precipitation occur along the radar range direction is important in determining how to allocate estimates of total path attenuation as derived either by the radiometer or by the use of the radar surface reference technique (Meneghini et al. 2000). Although hydrometeor identification has been studied for polarimetric radar (Ryzhkov and Zrnic 1998; Liu and Chandrasekar 2000; Dolan and Rutledge 2009), such research has not yet been well

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DOI: 10.1175/2010JAMC2499.1

Environmental Influences on the Strength of Tropical Storm Debby (2006)

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(Manuscript received 16 August 2010, in final form 30 June 2011)

ABSTRACT

This study uses mesoscale ensemble forecasts to compare the magnitude of nonaerosol effects of the Saharan air layer (SAL) with other environmental influences on the intensity of Tropical Storm Debby. Debby was a weak Cape Verde storm that dissipated over the tropical North Atlantic a few days after forming in August 2006. The system has received considerable attention because of its vicinity to the SAL as it struggled to intensify, which has led to speculation that the SAL helped lead to the storm's demise. Statistical correlation is used to better understand why some ensemble members strengthen the pre-Debby wave into a hurricane and others develop only a weak vortex.

Although the results here suggest that the SAL slowed intensification during the predepression to depression stages, it was not likely responsible for Debby's dissipation. The most obvious SAL-related factor to affect long-term intensity in the ensembles is dry air above 2 km, which delays organization of the low-level vortex. Warm temperatures within the SAL and shear associated with the African easterly jet (AEJ) exhibit a weak, secondary relationship with forecast intensity variability. An important result here is that sensitivity to the dry environmental air depends considerably on cyclone strength, and it becomes insignificant once a tropical storm forms. Furthermore, Debby's most rapid period of intensification coincided with its track over somewhat higher sea surface temperatures, and intensification ended when the storm moved over cooler waters. The results herein suggest that this factor might have affected the storm's intensity more strongly than did any effect of the SAL. Even later, subsequent to the period examined by these ensembles, Debby dissipated under the influence of stronger vertical wind shear from an upper-level trough.

These results show that the relationship among the SAL, AEJ, and developing tropical cyclones is not as straightforward as has been hypothesized by some recent studies. Ultimately, the nuanced relationship between storm intensity and the SAL shows that much care needs to be taken before drawing conclusions about the effect of the SAL on any particular cyclone. The authors therefore advocate more rigorous future analysis through both idealized and ensemble studies to more fully quantify the effect of the SAL on tropical cyclones in general.

1. Introduction

Considerable debate has recently evolved regarding the potential impacts of the Saharan air layer (SAL) on tropical cyclone genesis and intensification. The SAL, which is an elevated mixed layer with warm temperatures and low relative humidity, forms when westward-moving air crosses the Saharan desert and overrides cooler marine air over the Atlantic Ocean (Carlson and Prospero 1972; Prospero and Carlson 1981; Karyampudi and Carlson 1988). Early studies (e.g., Karyampudi and Carlson 1988; Karyampudi and Pierce 2002) suggested that the SAL positively influences the growth of African easterly waves (AEWs) and tropical cyclones in the Atlantic. However, a more recent study by Dunion and Velden (2004, hereafter DV04) suggested that increased vertical wind shear, dry low–midlevel air, and a strong low-level inversion associated with the SAL inhibit tropical cyclone formation and intensification. Although a number of recent studies have concurred with these findings for both individual systems (Wu et al. 2006; Jones et al. 2007; Shu and Wu 2009; Vizy and Cook 2009; Reale et al. 2009) and whole seasons (Lau and Kim 2007a,b; Sun et al. 2008), the results of Braun (2010a,b) and Braun et al.

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DOI: 10.1175/2011JAS3648.1

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JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 116, D02213, doi:10.1029/2010JD014438, 2011

Surface and atmospheric contributions to passive microwave brightness temperatures for falling snow events

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Received 30 April 2010; revised 16 September 2010; accepted 23 November 2010; published 29 January 2011.

[1] Physically based passive microwave precipitation retrieval algorithms require a set of relationships between satellite-observed brightness temperatures (TBs) and the physical state of the underlying atmosphere and surface. These relationships are nonlinear, such that inversions are ill-posed especially over variable land surfaces. In order to elucidate these relationships, this work presents a theoretical analysis using TB weighting functions to quantify the percentage influence of the TB resulting from absorption, emission, and/or reflection from the surface, as well as from frozen hydrometeors in clouds, from atmospheric water vapor, and from other contributors. The percentage analysis was also compared to Jacobians. The results are presented for frequencies from 10 to 874 GHz, for individual snow profiles, and for averages over three cloud-resolving model simulations of falling snow. The bulk structure (e.g., ice water path and cloud depth) of the underlying cloud scene was found to affect the resultant TB and percentages, producing different values for blizzard, lake effect, and synoptic snow events. The slant path at a 53° viewing angle increases the hydrometeor contributions relative to nadir viewing channels. Jacobians provide the magnitude and direction of change in the TB values due to a change in the underlying scene; however, the percentage analysis provides detailed information on how that change affected contributions to the TB from the surface, hydrometeors, and water vapor. The TB percentage information presented in this paper provides information about the relative contributions to the TB and supplies key pieces of information required to develop and improve precipitation retrievals over land surfaces.

Citation: Skofronick-Jackson, G., and B. T. Johnson (2011), Surface and atmospheric contributions to passive microwave brightness temperatures for falling snow events, *J. Geophys. Res.*, *116*, D02213, doi:10.1029/2010JD014438.

1. Introduction

[2] Because precipitation is a critical link in the Earth's global water and energy cycles, there is an interest in retrieving precipitation (both rain and snow) in an accurate and consistent fashion on a global basis. The use of satellite observations, such as those available from the upcoming NASA Global Precipitation Measurement (GPM) mission, provides scientists with the necessary spatial and temporal coverage. Crucial for developing physically based precipitation retrieval algorithms is an understanding of the physical relationships between satellite observations of the Earth and the state of the atmosphere and surface within the field of view. These characteristics are often nonlinear, are interrelated, and exhibit complex spatial structures and temporal variations. In general, the lower-frequency channels (10–37 GHz) are more sensitive to surface and absorptive or emissive warming from liquid rain, while the higher-frequency channels (85–874 GHz) are more sensitive to scattering from ice hydrometeors [e.g., *Evans et al.*, 2005]. Sounding channels near the water vapor absorption lines (23, 183, 325, and 448 GHz) respond primarily to the water vapor in the atmosphere and the absorption/emission continuum by water vapor generally increases with frequency. For hydrometeors, the amount, location, composition, and size distribution of the ice (and liquid) particles in the field of view produces varying brightness temperatures (TBs) for different frequencies and permits retrievals of rain rates from 0.2 to 110 mm h^{-1} [*Hou et al.*, 2008].

[3] Precipitation retrievals from space using channels from 10 to 183 GHz have become a mainstay in providing rainfall rate estimates globally as evidenced by the Tropical Rainfall Measuring Mission (TRMM) [e.g., *Kummerow et al.*, 2000], the Advanced Microwave Scanning Radiometer-Earth Observing System (AMSR-E) [*Kawanishi et al.*, 2003], and two Advanced Microwave Sounding Units (AMSU-A and AMSU-B) [e.g., *Ferraro et al.*, 2005]. The Ku band (13 GHz) radar aboard TRMM [*Kummerow et al.*, 2000] and the W band (94 GHz) radar aboard CloudSat [*Stephens et al.*, 2008] provide detailed limited-swath information about the vertical structure of cloud systems. The CloudSat radar responds primarily to cloud particles, light rain, and snow events, similar to that of high-frequency (>90 GHz) passive radiometer channels.

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0148-0227/11/2010JD014438

Asia-Pacific J. Atmos. Sci. 47(1), 1-16, 2011
DOI:10.1007/s13143-011-1001-z

The Impact of Microphysical Schemes on Hurricane Intensity and Track

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(Manuscript received 5 February 2010; revised 11 June 2010; accepted 6 July 2010)
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Abstract: During the past decade, both research and operational numerical weather prediction models [e.g. the Weather Research and Forecasting Model (WRF)] have started using more complex microphysical schemes originally developed for high-resolution cloud resolving models (CRMs) with 1-2 km or less horizontal resolutions. WRF is a next-generation meso-scale forecast model and assimilation system. It incorporates a modern software framework, advanced dynamics, numerics and data assimilation techniques, a multiple moveable nesting capability, and improved physical packages. WRF can be used for a wide range of applications, from idealized research to operational forecasting, with an emphasis on horizontal grid sizes in the range of 1-10 km. The current WRF includes several different microphysics options. At NASA Goddard, four different cloud microphysics options have been implemented into WRF. The performance of these schemes is compared to those of the other microphysics schemes available in WRF for an Atlantic hurricane case (Katrina). In addition, a brief review of previous modeling studies on the impact of microphysics schemes and processes on the intensity and track of hurricanes is presented and compared against the current Katrina study. In general, all of the studies show that microphysics schemes do not have a major impact on track forecasts but do have more of an effect on the simulated intensity. Also, nearly all of the previous studies found that simulated hurricanes had the strongest deepening or intensification when using only warm rain physics. This is because all of the simulated precipitating hydrometeors are large raindrops that quickly fall out near the eye-wall region, which would hydrostatically produce the lowest pressure. In addition, these studies suggested that intensities become unrealistically strong when evaporative cooling from cloud droplets and melting from ice particles are removed as this results in much weaker downdrafts in the simulated storms. However, there are many differences between the different modeling studies, which are identified and discussed.

Key words: Hurricane, microphysics, high-resolution modeling, precipitation processes

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1. Introduction

Advances in computing power allow atmospheric prediction models to be run at progressively finer scales of resolution, using increasingly more sophisticated physical parameterizations and numerical methods. The representation of cloud microphysical processes is a key component of these models. Over the past decade both research and operational numerical weather prediction (NWP) models [i.e., the Fifth-generation National Center for Atmospheric Research (NCAR) - Penn State University Mesoscale Model (MM5), the National Centers for Environmental Prediction (NCEP) Eta, and the Weather Research and Forecasting Model (WRF)] have started using more complex microphysical schemes that were originally developed for high-resolution cloud-resolving models (CRMs). CRMs, which are run at horizontal resolutions on the order of 1-2 km or finer, can simulate explicitly complex dynamical and microphysical processes associated with deep, precipitating atmospheric convection. A recent report to the United States Weather Research Program (USWRP) Science Steering Committee specifically calls for the replacement of implicit cumulus parameterization schemes with explicit bulk schemes in NWP as part of a community effort to improve quantitative precipitation forecasts (QPF, Fritsch and Carbone, 2002).

There is no doubt that cloud microphysics play an important role in non-hydrostatic high-resolution simulations as evidenced by the extensive amount of research devoted to the development and improvement of cloud microphysical schemes and their application to the study of precipitation processes, hurricanes and other severe weather events over the past two and a half decades (see Table 1). Many different approaches have been used to examine the impact of microphysics on precipitation processes associated with convective systems*. For example, ice phase schemes were developed in the 80's (Lin *et al.,* 1983; Cotton *et*

*The effects of aerosols [see a brief review by Tao *et al*. (2007)] on microphysical (processes) schemes have also been studied.

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 116, D21118, doi:10.1029/2011JD016610, 2011

The relative importance of random error and observation frequency in detecting trends in upper tropospheric water vapor

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Received 27 July 2011; revised 7 September 2011; accepted 13 September 2011; published 12 November 2011.

[1] Recent published work assessed the amount of time to detect trends in atmospheric water vapor over the coming century. We address the same question and conclude that under the most optimistic scenarios and assuming perfect data (i.e., observations with no measurement uncertainty) the time to detect trends will be at least 12 years at approximately 200 hPa in the upper troposphere. Our times to detect trends are therefore shorter than those recently reported and this difference is affected by data sources used, method of processing the data, geographic location and pressure level in the atmosphere where the analyses were performed. We then consider the question of how instrumental uncertainty plays into the assessment of time to detect trends. We conclude that due to the high natural variability in atmospheric water vapor, the amount of time to detect trends in the upper troposphere is relatively insensitive to instrumental random uncertainty and that it is much more important to increase the frequency of measurement than to decrease the random error in the measurement. This is put in the context of international networks such as the Global Climate Observing System (GCOS) Reference Upper-Air Network (GRUAN) and the Network for the Detection of Atmospheric Composition Change (NDACC) that are tasked with developing time series of climate quality water vapor data.

Citation: Whiteman, D. N., K. C. Vermeesch, L. D. Oman, and E. C. Weatherhead (2011), The relative importance of random error and observation frequency in detecting trends in upper tropospheric water vapor, *J. Geophys. Res.*, *116*, D21118, doi:10.1029/2011JD016610.

1. Introduction

[2] Water vapor is one of the most important components of the atmosphere when considering atmospheric chemistry, radiation, dynamics and clouds. For example, increases in stratospheric water vapor can lead to cooling of the stratosphere, warming of the troposphere [*Forster and Shine*, 2002] and delay the recovery of ozone [*Shindell*, 2001; *Weatherhead and Andersen*, 2006]. *Solomon et al.* [2010] have recently shown that decreases in lower stratospheric water vapor have slowed the rate of global surface temperature increase over the last decade. Trends in upper tropospheric water vapor concentrations and temperature will influence cirrus cloud frequency and composition. For these reasons and others, significant effort has been put into both measurements and modeling of UT/LS water vapor to assess long-term trends in water vapor concentrations and thus address the consequences of changes in UT/LS water vapor amounts.

[3] A recent work by *Boers and van Meijgaard* [2009] (hereafter referred to as BM2009) considered an ensemble of 150-year simulations of upper tropospheric water vapor at 300 hPa over the Netherlands using a regional climate model to study the measurement needs for revealing trends in atmospheric water vapor. Their simulations indicated nearly a doubling in upper tropospheric water vapor concentration over the coming century. Applying a well-known statistical model [*Weatherhead et al.*, 1998] to their time series indicated that a statistically significant trend in water vapor concentration could be discerned within 30 years using a perfect data set with no random errors imposed. We have studied the same problem using a global climate model, different data sources, different geographic location, and different pressure levels. We then extend our discussion to the main purpose of this paper, which is to consider the relative importance of observation random error and observation frequency on the time to detect trends.

2. Trend Detection Tools

[4] The statistical model employed here, which assumes autoregressive of the order 1 (AR-1) behavior in the data, is that described by *Weatherhead et al.* [1998, 2002] and is the same as used in BM2009. We summarize here the technique

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0148-0227/11/2011JD016610

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 116, D24105, doi:10.1029/2011JD016466, 2011

A novel nonintrusive method to resolve the thermal dome effect of pyranometers: Radiometric calibration and implications

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Received 26 June 2011; revised 30 September 2011; accepted 16 October 2011; published 17 December 2011.

[1] Traditionally the calibration equation for pyranometers assumes that the measured solar irradiance is solely proportional to the thermopile's output voltage; therefore, only a single calibration factor is derived. This causes additional measurement uncertainties because it does not capture sufficient information to correctly account for a pyranometer's thermal effect. In our updated calibration equation, temperatures from the pyranometer's dome and case are incorporated to describe the instrument's thermal behavior, and a new set of calibration constants are determined, thereby reducing measurement uncertainties. In this paper, we demonstrate why a pyranometer's uncertainty using the traditional calibration equation is always larger than a few percent, but with the new approach can become much less than 1% after the thermal issue is resolved. The highlighted calibration results are based on NIST traceable light sources under controlled laboratory conditions. The significance of the new approach lends itself to not only avoiding the uncertainty caused by a pyranometer's thermal effect but also the opportunity to better isolate and characterize other instrumental artifacts, such as angular response and nonlinearity of the thermopile, to further reduce additional uncertainties. We also discuss some of the implications, including an example of how the thermal issue can potentially impact climate studies by evaluating aerosol's direct radiative effect using field measurements with and without considering the pyranometer's thermal effect. The results of radiative transfer model simulation show that a pyranometer's thermal effect on solar irradiance measurements at the surface can be translated into a significant alteration of the calculated distribution of solar energy inside the column atmosphere.

Citation: Ji, Q., S.-C. Tsay, K. M. Lau, R. A. Hansell, J. J. Butler, and J. W. Cooper (2011), A novel nonintrusive method to resolve the thermal dome effect of pyranometers: Radiometric calibration and implications, *J. Geophys. Res.*, *116*, D24105, doi:10.1029/2011JD016466.

1. Introduction

[2] The measurements of solar irradiance over the globe play an important role in climate studies because solar radiation is the primary driving force of climate. Pyranometers are used worldwide to measure solar irradiance. Traditionally, the uncertainty of a high-quality pyranometer is greater than a few percent, which is not desired for studying long-term climate change. For example, the radiative forcing due to doubling the amount of CO_2 in the atmosphere is $\sim$4 W m^{-2} [*Ad Hoc Study Group on Carbon Dioxide and Climate*, 1979], and the global average of radiative forcing for different agents and mechanisms is around a couple of W m^{-2} [*Pachauri and Reisinger*, 2007]. However, a $\pm$ 2% uncertainty (specifications of pyranometer) [e.g., *World Meteorological Organization* (*WMO*), 2008] on the $\sim$184 W m^{-2} ($\sim$263 W m^{-2} if cloud free) global annual mean solar radiation at the Earth's surface [*Trenberth et al.*, 2009] is over $\pm$ 3.6 W m^{-2}, comparable to or larger than the expected ranges of the climate change signals. A reduced uncertainty in pyranometer measurements will have profound implications, such as gaining the ability to better discern the radiative forcing, or the global dimming and brightening [*Wild*, 2009]. Furthermore, a more accurate data set of solar irradiance will also help improve the evaluation of the effects of clouds and aerosols on climate studies. An example of the latter effect is explored later in the paper.

[3] A pyranometer's larger than 2%$\sim$3% uncertainty [*WMO*, 2008] is related to its thermal dome effect (TDE), which traditionally is not quantified. Shading a pyranometer can help reveal and infer its thermal effect [e.g., *Gulbrandsen*, 1978]; however, it does not provide a direct nonintrusive measurement of TDE. In addition, any object casting the shade also imposes its own contribution dynamically to the thermal environment. This situation has changed since the studies that explicitly describe the TDE [e.g., *Bush et al.*, 2000; *Ji and Tsay*, 2000; *Haeffelin et al.*,

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0148-0227/11/2011JD016466

Surv Geophys
DOI 10.1007/s10712-011-9153-z

Reducing the Uncertainties in Direct Aerosol Radiative Forcing

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Received: 26 July 2011 / Accepted: 11 October 2011
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Abstract Direct aerosol radiative forcing (DARF) remains a leading contributor to climate prediction uncertainty. To monitor the spatially and temporally varying global atmospheric aerosol load, satellite remote sensing is required. Despite major advances in observing aerosol amount, type, and distribution from space, satellite data alone cannot provide enough quantitative detail, especially about aerosol microphysical properties, to effect the required improvement in estimates of DARF and the anthropogenic component of DARF. However, the combination of space-based and targeted suborbital measurements, when used to constrain climate models, represents an achievable next step likely to provide the needed advancement.

Keywords Aerosol remote sensing · Direct aerosol radiative forcing

1 Introduction

Airborne particles, which include desert and soil dust, wildfire smoke, sea salt, volcanic ash, black carbon, natural and anthropogenic sulfate, nitrate, and organic aerosol, affect Earth's energy budget both directly, by reflecting and absorbing sunlight, and indirectly, by altering cloud microphysical processes. This paper reviews the current status, and evaluates future prospects for quantifying a major component of the aerosol influence on Earth's climate system, through the direct radiative impact on incoming solar radiation. Aerosol-cloud interactions, and the indirect aerosol radiative effects that these produce, are beyond the scope of the current paper. Global-scale observational constraints on the indirect processes are much less well established and, as such, the continuum between "clear-sky" conditions, which are the subject of this paper, and "all-sky" conditions (e.g., Várnai and Marshak 2011), is considered here only in the context of the cloud masking techniques applied to aerosol remote-sensing observations.

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Published online: 27 October 2011

Springer

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 116, D03210, doi:10.1029/2010JD014985, 2011

Multiangle implementation of atmospheric correction (MAIAC): 1. Radiative transfer basis and look-up tables

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Received 31 August 2010; revised 3 November 2010; accepted 30 November 2010; published 11 February 2011.

[1] This paper describes a radiative transfer basis of the algorithm MAIAC which performs simultaneous retrievals of atmospheric aerosol and bidirectional surface reflectance from the Moderate Resolution Imaging Spectroradiometer (MODIS). The retrievals are based on an accurate semianalytical solution for the top-of-atmosphere reflectance expressed as an explicit function of three parameters of the Ross–Thick Li–Sparse model of surface bidirectional reflectance. This solution depends on certain functions of atmospheric properties and geometry which are precomputed in the look-up table (LUT). This paper further considers correction of the LUT functions for variations of surface pressure/height and of atmospheric water vapor, which is a common task in the operational remote sensing. It introduces a new analytical method for the water vapor correction of the multiple-scattering path radiance. It also summarizes the few basic principles that provide a high efficiency and accuracy of the LUT-based radiative transfer for the aerosol/surface retrievals and optimize the size of LUT. For example, the single-scattering path radiance is calculated analytically for a given surface pressure and atmospheric water vapor. The same is true for the direct surface-reflected radiance, which along with the single-scattering path radiance largely defines the angular dependence of measurements. For these calculations, the aerosol phase functions and kernels of the surface bidirectional reflectance model are precalculated at a high angular resolution. The other radiative transfer functions depend rather smoothly on angles because of multiple scattering and can be calculated at coarser angular resolution to reduce the LUT size. At the same time, this resolution should be high enough to use the nearest neighbor geometry angles to avoid costly three-dimensional interpolation. The pressure correction is implemented via linear interpolation between two LUTs computed for the standard and reduced pressure levels. A linear mixture and a modified linear mixture methods are used to represent different aerosol types in the aerosol/surface retrievals from several base models of the fine and coarse aerosol fractions. In summary, the developed LUT algorithm allows fast high-accuracy simulations of the outgoing radiance with full variability of the atmospheric and surface bidirectional reflectance properties for the aerosol/surface remote sensing.

Citation: Lyapustin, A., J. Martonchik, Y. Wang, I. Laszlo, and S. Korkin (2011), Multiangle implementation of atmospheric correction (MAIAC): 1. Radiative transfer basis and look-up tables, *J. Geophys. Res.*, *116*, D03210, doi:10.1029/2010JD014985.

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[2] Operational remote sensing of the Earth' aerosol and surface reflectance is based on the look-up tables (LUT). The LUTs store precomputed radiative transfer (RT) functions that allow fast and accurate modeling of the top-of-the-atmosphere (TOA) radiance for sensor's wavelengths as a function of view geometry and atmosphere-surface parameters. A Lambertian surface assumption, used in developed MODIS aerosol retrieval [*Levy et al.*, 2007; *Hsu et al.*, 2005 and atmospheric correction [*Vermote and Kotchenova*, 2008] algorithms, simplifies the mathematics and keeps the LUT size low. At the same time, accurate accounting for variations of the MODIS view geometry requires explicit incorporation of the surface bidirectional reflectance in the LUT algorithm and in the aerosol-surface retrievals. Such an approach was developed by *Martonchik et al.* [1998] for MISR and later by *Pinty et al.* [2000] for Meteosat. Here

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0148-0227/11/2010JD014985

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 116, D03211, doi:10.1029/2010JD014986, 2011

Multiangle implementation of atmospheric correction (MAIAC): 2. Aerosol algorithm

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Received 31 August 2010; revised 4 November 2010; accepted 2 December 2010; published 11 February 2011.

[1] An aerosol component of a new multiangle implementation of atmospheric correction (MAIAC) algorithm is presented. MAIAC is a generic algorithm developed for the Moderate Resolution Imaging Spectroradiometer (MODIS), which performs aerosol retrievals and atmospheric correction over both dark vegetated surfaces and bright deserts based on a time series analysis and image-based processing. The MAIAC look-up tables explicitly include surface bidirectional reflectance. The aerosol algorithm derives the spectral regression coefficient (SRC) relating surface bidirectional reflectance in the blue (0.47 μm) and shortwave infrared (2.1 μm) bands; this quantity is prescribed in the MODIS operational Dark Target algorithm based on a parameterized formula. The MAIAC aerosol products include aerosol optical thickness and a fine-mode fraction at resolution of 1 km. This high resolution, required in many applications such as air quality, brings new information about aerosol sources and, potentially, their strength. AERONET validation shows that the MAIAC and MOD04 algorithms have similar accuracy over dark and vegetated surfaces and that MAIAC generally improves accuracy over brighter surfaces due to the SRC retrieval and explicit bidirectional reflectance factor characterization, as demonstrated for several U.S. West Coast AERONET sites. Due to its generic nature and developed angular correction, MAIAC performs aerosol retrievals over bright deserts, as demonstrated for the Solar Village Aerosol Robotic Network (AERONET) site in Saudi Arabia.

Citation: Lyapustin, A., Y. Wang, I. Laszlo, R. Kahn, S. Korkin, L. Remer, R. Levy, and J. S. Reid (2011), Multiangle implementation of atmospheric correction (MAIAC): 2. Aerosol algorithm, *J. Geophys. Res.*, *116*, D03211, doi:10.1029/2010JD014986.

1. Introduction

[2] The Earth Observing System [*King and Greenstone*, 1999] initiated high-quality global Earth observations and operational aerosol retrievals over land. With the wide-swath (2300 km) MODIS instrument, the MODIS Dark Target [*Kaufman et al.*, 1997; *Remer et al.*, 2005; *Levy et al.*, 2007] and Deep Blue algorithms [*Hsu et al.*, 2004] provide a daily global view of planetary atmospheric aerosol loading. The MISR algorithm [*Martonchik et al.*, 1998; *Diner et al.*, 2005; *Kahn et al.*, 2005] makes high-quality aerosol retrievals in 380 km swaths covering the globe in 8 days.

[3] With the general success of the MODIS aerosol program, the issue of surface characterization remains high on the list of priorities. Unlike MISR, which uses multiangle observations for simultaneous aerosol-surface retrievals, the current MODIS processing is pixel-based and relies on a single-orbit data. For every pixel, this approach produces a single measurement characterized by two main unknowns, aerosol optical thickness (AOT) and surface reflectance (SR). This lack of information constitutes a fundamental problem of the remote sensing that cannot be resolved without a priori information. For this reason, the MODIS Dark Target algorithm makes spectral assumptions about surface reflectance, whereas the Deep Blue method uses an ancillary global surface reflectance database. Both algorithms use a Lambertian surface model and apply an empirical correction for surface anisotropy. The aerosol product errors from the surface model have been well documented [e.g., *Drury et al.*, 2008; *Kahn et al.*, 2009; *Wang et al.*, 2007; H. J. Hyer et al., An over-land aerosol optical depth data set for data assimilation by filtering, correction, and aggregation of MODIS Collection 5 optical depth retrievals, submitted to Atmospheric *Chemistry and Physics*, 2010].

[4] This and a companion paper (A. Lyapustin et al., Multiangle implementation of atmospheric correction

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0148-0227/11/2010JD014986

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Spectrally Invariant Approximation within Atmospheric Radiative Transfer

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(Manuscript received 14 February 2011, in final form 25 May 2011)

ABSTRACT

Certain algebraic combinations of single scattering albedo and solar radiation reflected from, or transmitted through, vegetation canopies do not vary with wavelength. These ''spectrally invariant relationships'' are the consequence of wavelength independence of the extinction coefficient and scattering phase function in vegetation. In general, this wavelength independence does not hold in the atmosphere, but in cloud-dominated atmospheres the total extinction and total scattering phase function vary only weakly with wavelength. This paper identifies the atmospheric conditions under which the spectrally invariant approximation can accurately describe the extinction and scattering properties of cloudy atmospheres. The validity of the assumptions and the accuracy of the approximation are tested with 1D radiative transfer calculations using publicly available radiative transfer models: Discrete Ordinate Radiative Transfer (DISORT) and Santa Barbara DISORT Atmospheric Radiative Transfer (SBDART). It is shown for cloudy atmospheres with cloud optical depth above 3, and for spectral intervals that exclude strong water vapor absorption, that the spectrally invariant relationships found in vegetation canopy radiative transfer are valid to better than 5%. The physics behind this phenomenon, its mathematical basis, and possible applications to remote sensing and climate are discussed.

1. Introduction

Recently several papers reported the discovery of spectrally invariant behavior in some simple algebraic combinations, called ''spectral invariants,'' of single scattering albedo and solar radiation reflected from or transmitted through vegetation canopies (Knyazikhin et al. 1998, 2005; Huang et al. 2007). The spectral invariant phenomenon is clearly seen in radiative measurements and remote sensing data (Panferov et al. 2001; Wang et al. 2003). The phenomenon was theoretically explained and numerically simulated using radiative transfer theory (Knyazikhin et al. 2011; Smolander and Stenberg 2005). There are three key parameters that characterize the radiative transfer process: the extinction coefficient, scattering phase function, and single scattering albedo. In vegetation, the optical distance between two points within the canopy does not depend on wavelength because the scattering elements are much larger than the wavelength of solar radiation (Ross 1981). And the canopy scattering phase function is also wavelength independent since it is determined by large scattering elements such as twigs and leaves. Thus, of the three key variables, the single scattering albedo is the only one with significant wavelength dependency. This allows for a natural separation between structural and spectral parameters of radiative transfer: the extinction coefficient

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DOI: 10.1175/JAS-D-11-060.1

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 116, D02210, doi:10.1029/2010JD014861, 2011

Influence of dust and black carbon on the snow albedo in the NASA Goddard Earth Observing System version 5 land surface model

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Received 4 August 2010; revised 25 October 2010; accepted 18 November 2010; published 27 January 2011.

[1] Present-day land surface models rarely account for the influence of both black carbon and dust in the snow on the snow albedo. Snow impurities increase the absorption of incoming shortwave radiation (particularly in the visible bands), whereby they have major consequences for the evolution of snowmelt and life cycles of snowpack. A new parameterization of these snow impurities was included in the catchment-based land surface model used in the National Aeronautics and Space Administration Goddard Earth Observing System version 5. Validation tests against in situ observed data were performed for the winter of 2003–2004 in Sapporo, Japan, for both the new snow albedo parameterization (which explicitly accounts for snow impurities) and the preexisting baseline albedo parameterization (which does not). Validation tests reveal that daily variations of snow depth and snow surface albedo are more realistically simulated with the new parameterization. Reasonable perturbations in the assigned snow impurity concentrations, as inferred from the observational data, produce significant changes in snowpack depth and radiative flux interactions. These findings illustrate the importance of parameterizing the influence of snow impurities on the snow surface albedo for proper simulation of the life cycle of snow cover.

Citation: Yasunari, T. J., R. D. Koster, K.-M. Lau, T. Aoki, Y. C. Sud, T. Yamazaki, H. Motoyoshi, and Y. Kodama (2011), Influence of dust and black carbon on the snow albedo in the NASA Goddard Earth Observing System version 5 land surface model, *J. Geophys. Res.*, *116*, D02210, doi:10.1029/2010JD014861.

1. Introduction

[2] A large amount of water, roughly 24 million km^3, is stored in present-day glaciers and snow packs [*Oki and Kanae*, 2006]. These reservoirs vary in size over the annual cycle, thereby affecting available water resources in many regions of the world [e.g., *Mote*, 2003; *Yao et al.*, 2004]. As noted in scores of studies [e.g., *Barnett et al.*, 1989; *Zhang et al.*, 2004], changes in snow cover and depth can also affect the surface fluxes that in turn modulate the atmospheric circulation and, accordingly, climate.

[3] Snow albedo is a critical player in the growth and ablation of snowpack; a higher albedo implies less available energy for melting or sublimating snow. Several factors work together to determine snow albedo, including snow grain size (branch width and length for dendrite snow cases), solar zenith angle (SZA), liquid water content, and snow impurities [*Wiscombe and Warren*, 1980; *Warren and Wiscombe*, 1980; *Grenfell et al.*, 1994; *Aoki et al.*, 1999, 2000, 2006, 2007; *Motoyoshi et al.*, 2005; *Tanikawa et al.*, 2006, 2009; *Flanner et al.*, 2007; *Aoki and Tanaka*, 2008]. Here we examine a factor that is often neglected in the snow albedo component of land surface model (LSM) studies: the deposition of atmospheric black carbon and dust (BCD) onto the snow surface, which are well-known absorbers of solar radiation [e.g., *Warren and Wiscombe*, 1980, 1985; *Aoki et al.*, 2000; *Hansen and Nazarenko*, 2004; *Flanner et al.*, 2007; *Aoki and Tanaka*, 2008]. Through their radiative effects on snow [e.g., *Lau et al.*, 2006, 2010; *IPCC*, 2007], these aerosols can, in turn, affect the life cycle of the snowpack, the surface heat budget, and the atmospheric circulation. The long-range transport of BCD is well documented [e.g., *Hadley et al.*, 2007; *Yasunari et al.*, 2007; *Yasunari and Yamazaki*, 2009; *Uno et al.*, 2009], implying that aerosol emission in one part of the globe can affect snowpack optical properties and evolution in another.

[4] The impact of deposited black carbon (BC) on melt water from Himalayan glaciers is a major concern for people living in the Indo-Gangetic Plains and eastern China, where meltwater runoff is a primary source of potable water and

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0148-0227/11/2010JD014861

Atmos. Chem. Phys., 11, 8515–8541, 2011
www.atmos-chem-phys.net/11/8515/2011/
doi:10.5194/acp-11-8515-2011
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Atmospheric Chemistry and Physics

A model study of the impact of source gas changes on the stratosphere for 1850–2100

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Received: 4 March 2011 – Published in Atmos. Chem. Phys. Discuss.: 12 April 2011
Revised: 3 August 2011 – Accepted: 6 August 2011 – Published: 22 August 2011

Abstract. The long-term stratospheric impacts due to emissions of CO_2, CH_4, N_2O, and ozone depleting substances (ODSs) are investigated using an updated version of the Goddard two-dimensional (2-D) model. Perturbation simulations with the ODSs, CO_2, CH_4, and N_2O varied individually are performed to isolate the relative roles of these gases in driving stratospheric changes over the 1850–2100 time period. We also show comparisons with observations and the Goddard Earth Observing System chemistry-climate model simulations for the time period 1960–2100 to illustrate that the 2-D model captures the basic processes responsible for long-term stratospheric change.

The ODSs, CO_2, CH_4, and N_2O impact ozone via several mechanisms. ODS and N_2O loading decrease stratospheric ozone via the increases in atmospheric halogen and odd nitrogen species, respectively. CO_2 loading impacts ozone by: (1) cooling the stratosphere which increases ozone via the reduction in the ozone chemical loss rates, and (2) accelerating the Brewer-Dobson circulation (BDC) which redistributes ozone in the lower stratosphere. The net result of CO_2 loading is an increase in global ozone in the total column and upper stratosphere. CH_4 loading impacts ozone by: (1) increasing atmospheric H_2O and the odd hydrogen species which decreases ozone via the enhanced HOx-ozone loss rates; (2) increasing the H_2O cooling of the middle atmosphere which reduces the ozone chemical loss rates, partially offsetting the enhanced HOx-ozone loss; (3) converting active to reservoir chlorine via the reaction $CH_4+Cl \rightarrow HCl+CH_3$ which leads to more ozone; and (4) increasing the NO_x-ozone production in the troposphere. The net result of CH_4 loading is an ozone decrease above 40–45 km, and an increase below 40–45 km and in the total column.

The 2-D simulations indicate that prior to 1940, the ozone increases due to CO_2 and CH_4 loading outpace the ozone losses due to increasing N_2O and carbon tetrachloride (CCl_4) emissions, so that total column and upper stratospheric global ozone reach broad maxima during the 1920s–1930s. This precedes the significant ozone depletion during ~1960–2050 driven by the ODS loading. During the latter half of the 21st century as ODS emissions diminish, CO_2, N_2O, and CH_4 loading will all have significant impacts on global total ozone based on the Intergovernmental Panel on Climate Change (IPCC) A1B (medium) scenario, with CO_2 having the largest individual effect. Sensitivity tests illustrate that due to the strong chemical interaction between methane and chlorine, the CH_4 impact on total ozone becomes significantly more positive with larger ODS loading. The model simulations also show that changes in stratospheric temperature, BDC, and age of air during 1850–2100 are controlled mainly by the CO_2 and ODS loading. The simulated acceleration of the BDC causes the global average age of air above 22 km to decrease by ~1 yr from 1860–2100. The photochemical lifetimes of N_2O, $CFCl_3$, CF_2Cl_2, and CCl_4 decrease by 11–13 % during 1960–2100 due to the acceleration of the BDC, with much smaller lifetime changes (<4 %) caused by changes in the photochemical loss rates.

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Published by Copernicus Publications on behalf of the European Geosciences Union.

Biogeosciences, 8, 637–651, 2011
www.biogeosciences.net/8/637/2011/
doi:10.5194/bg-8-637-2011
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Biogeosc

First observations of global and seasonal terrestrial chlorophyll fluorescence from space

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Received: 19 October 2010 – Published in Biogeosciences Discuss.: 11 November 2010
Revised: 27 February 2011 – Accepted: 1 March 2011 – Published: 8 March 2011

Abstract. Remote sensing of terrestrial vegetation fluorescence from space is of interest because it can potentially provide global coverage of the functional status of vegetation. For example, fluorescence observations may provide a means to detect vegetation stress before chlorophyll reductions take place. Although there have been many measurements of fluorescence from ground- and airborne-based instruments, there has been scant information available from satellites. In this work, we use high-spectral resolution data from the Thermal And Near-infrared Sensor for carbon Observation – Fourier Transform Spectrometer (TANSO-FTS) on the Japanese Greenhouse gases Observing SATellite (GOSAT) that is in a sun-synchronous orbit with an equator crossing time near 13:00 LT. We use filling-in of the potassium (K) I solar Fraunhofer line near 770 nm to derive chlorophyll fluorescence and related parameters such as the fluorescence yield at that wavelength. We map these parameters globally for two months (July and December 2009) and show a full seasonal cycle for several different locations, including two in the Amazonia region. We also compare the derived fluorescence information with that provided by the MODIS Enhanced Vegetation Index (EVI). These comparisons show that for several areas these two indices exhibit different seasonality and/or relative intensity variations, and that changes in fluorescence frequently lead those seen in the EVI for those regions. The derived fluorescence therefore provides information that is related to, but independent of the reflectance.

1 Introduction

Vegetation is the functional interface between th
restrial biosphere and the atmosphere. Terrestria
absorb approximately 120 Gt of carbon annuall
physiological process of photosynthesis. Abou
carbon is released by ecosystem respiration pro
short time periods. The remaining carbon is r
Net Primary Production (NPP). Disturbances a
changes of ecosystems release parts of this carb
time frame of centuries. There are currently gre
ties for the human impact on the magnitude
cesses.

Photosynthesis is the conversion by living
light energy into chemical energy and fixation of
carbon dioxide into sugars; it is the key proce
90% of carbon and water fluxes in the couple
atmosphere system. Until now, most of the inf
has been acquired by remote sensing of the Ea
about vegetation conditions has come from refl
the solar domain. There is, however, one additio
information about vegetation productivity in th
near-infrared wavelength range that has not beer
ploited by satellite observations. This source o
is related to the emission of fluorescence fron
phyll of assimilating leaves; part of the energy
chlorophyll cannot be used for carbon fixation a
emitted as fluorescence at longer wavelengths (l
with respect to the absorption.

GEOPHYSICAL RESEARCH LETTERS, VOL. 38, L13706, doi:10.1029/2011GL047865, 2011

The response of tropical tropospheric ozone to ENSO

L. D. Oman,[1] J. R. Ziemke,[1,2] A. R. Douglass,[1] D. W. Waugh,[3] C. Lang,[3]
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Received 19 April 2011; revised 2 June 2011; accepted 5 June 2011; published 13 July 2011.

[1] We have successfully reproduced the Ozone ENSO Index (OEI) in the Goddard Earth Observing System (GEOS) chemistry-climate model (CCM) forced by observed sea surface temperatures over a 25-year period. The vertical ozone response to ENSO is consistent with changes in the Walker circulation. We derive the sensitivity of simulated ozone to ENSO variations using linear regression analysis. The western Pacific and Indian Ocean region shows similar positive ozone sensitivities from the surface to the upper troposphere, in response to positive anomalies in the Niño 3.4 Index. The eastern and central Pacific region shows negative sensitivities with the largest sensitivity in the upper troposphere. This vertical response compares well with that derived from SHADOZ ozonesondes in each region. The OEI reveals a response of tropospheric ozone to circulation change that is nearly independent of changes in emissions and thus it is potentially useful in chemistry-climate model evaluation. **Citation:** Oman, L. D., J. R. Ziemke, A. R. Douglass, D. W. Waugh, C. Lang, J. M. Rodriguez, and J. E. Nielsen (2011), The response of tropical tropospheric ozone to ENSO, *Geophys. Res. Lett.*, *38*, L13706, doi:10.1029/2011GL047865.

1. Introduction

[2] The El Niño-Southern Oscillation (ENSO) is the dominant mode of tropical variability on interannual timescales [*Philander*, 1989]. ENSO has been long known to cause significant perturbations to the coupled oceanic and atmospheric circulations [*Bjerknes*, 1969; *Enfield*, 1989]. Changes in sea surface temperatures in the Pacific Ocean can notably impact the Walker Circulation, displacing areas of convective activity, and have also been shown to dominate the interannual variability of the Hadley cell [*Quan et al.*, 2004]. These changes in circulation cause changes in the temperature and moisture fields across the tropical Pacific, and influence the constituent distributions in the troposphere [*Chandra et al.*, 1998, 2002, 2009; *Sudo and Takahashi*, 2001; *Ziemke and Chandra*, 2003; *Zeng and Pyle*, 2005; *Doherty et al.*, 2006; *Lee et al.*, 2010; *Randel and Thompson*, 2011] and in the stratosphere [*Randel and Cobb*, 1994].

[3] *Ziemke et al.* [2010] used tropospheric column ozone (TCO) measurements to show that the ENSO related response of tropospheric ozone over the western and eastern Pacific dominated interannual variability. The ENSO impact is so clearly seen in tropospheric ozone columns that an Ozone ENSO Index (OEI) that largely mimics the Niño 3.4 Index is formed by subtracting the eastern and central tropical Pacific region TCO (15°S–15°N, 110°W–180°W) from the western tropical Pacific-Indian Ocean region (15°S–15°N, 70°E–140°E), removing the seasonal cycle and smoothing with a 3-month running average. *Ziemke et al.* [2010] suggested that chemistry-climate models forced with observed sea surface temperatures should reproduce this observed pattern in tropospheric ozone. Here we will show that in the GEOS CCM tropical tropospheric ozone responds to the perturbation in atmospheric dynamics that is due to the ENSO signature in tropical SSTs. In addition, we use the Southern Hemisphere Additional Ozonesondes (SHADOZ) measurements to evaluate the vertical structure of the simulated response to ENSO.

2. Model Simulation and Measurements

[4] We examine the response of simulated tropospheric ozone to the observed sea surface temperature changes using the Goddard Earth Observing System (GEOS) version 5 general circulation model [*Rienecker et al.*, 2008] coupled to the comprehensive Global Modeling Initiative (GMI) stratosphere-troposphere chemical mechanism [*Duncan et al.*, 2007; *Strahan et al.*, 2007]. The GMI combined stratosphere-troposphere chemistry mechanism includes 117 species, 322 chemical reactions, and 81 photolysis reactions. Integration of the chemical mass balance equations use the SMVGEAR II algorithm described by *Jacobson* [1995]. The mechanism includes a detailed description of O_3-NO_x-hydrocarbon chemistry necessary for the troposphere [*Bey et al.*, 2001], with more recent updates described by *Duncan et al.* [2007]. The simulation used in this study was forced with observed sea surface temperatures and sea ice concentrations from 1985 to 2009 (*Rayner et al.* [2003], updated on a monthly basis), but the seasonally-varying mixing ratio boundary conditions and emissions for trace gases are for 2005 conditions. The simulation produces the variability in constituent distributions due to sea surface temperature changes that we evaluate here.

[5] A record of TCO for the 2005–2010 period was derived from the combination of NASA's Aura satellite Ozone Monitoring Instrument (OMI) and the Microwave Limb Sounder (MLS) using the method described by *Ziemke et al.* [2006]. These TCO values extend the time series developed using Nimbus 7 TOMS, Earth Probe TOMS and NOAA SBUV. The TCO measurements for 2005–2010 are used in Figure 1a. A complete description of the methods used to construct the OEI is given by *Ziemke et al.* [2010]. Here we use the index derived from TCO measurements for 1985–2009 to match the simulation. The OEI time series begins in 1979 and is updated periodically. The data can be obtained

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0094-8276/11/2011GL047865

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 116, D17302, doi:10.1029/2010JD015360, 2011

Using transport diagnostics to understand chemistry climate model ozone simulations

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Received 19 November 2010; revised 13 May 2011; accepted 13 June 2011; published 9 September 2011.

[1] We use observations of N_2O and mean age to identify realistic transport in models in order to explain their ozone predictions. The results are applied to 15 chemistry climate models (CCMs) participating in the 2010 World Meteorological Organization ozone assessment. Comparison of the observed and simulated N_2O, mean age and their compact correlation identifies models with fast or slow circulations and reveals details of model ascent and tropical isolation. This process-oriented diagnostic is more useful than mean age alone because it identifies models with compensating transport deficiencies that produce fortuitous agreement with mean age. The diagnosed model transport behavior is related to a model's ability to produce realistic lower stratosphere (LS) O_3 profiles. Models with the greatest tropical transport problems compare poorly with O_3 observations. Models with the most realistic LS transport agree more closely with LS observations and each other. We incorporate the results of the chemistry evaluations in the Stratospheric Processes and their Role in Climate (SPARC) CCMVal Report to explain the range of CCM predictions for the return-to-1980 dates for global (60°S–60°N) and Antarctic column ozone. Antarctic O_3 return dates are generally correlated with vortex Cl_y levels, and vortex Cl_y is generally correlated with the model's circulation, although model Cl chemistry and conservation problems also have a significant effect on return date. In both regions, models with good LS transport and chemistry produce a smaller range of predictions for the return-to-1980 ozone values. This study suggests that the current range of predicted return dates is unnecessarily broad due to identifiable model deficiencies.

Citation: Strahan, S. E., et al. (2011), Using transport diagnostics to understand chemistry climate model ozone simulations, *J. Geophys. Res.*, *116*, D17302, doi:10.1029/2010JD015360.

1. Introduction

[2] Chemistry climate models (CCMs) are the current state-of-the-art tools used to assess stratospheric ozone and make predictions of its future evolution [*World Meteorological Organization* (*WMO*), 2011, 2007]. Ozone distributions are controlled by transport, chemistry, and temperature (i.e., dynamics and radiation). In the stratosphere, the processes that control ozone are expressed by the ozone tendency equation,

$$d\mathrm{O}_3/dt = \mathrm{Transport} + \mathrm{P} - \mathrm{L}(\mathrm{O}_x) - \mathrm{L}(\mathrm{NO}_x) - \mathrm{L}(\mathrm{Cl}_x) - \mathrm{L}(\mathrm{Br}_x) - \mathrm{L}(\mathrm{HO}_x),$$

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0148-0227/11/2010JD015360

Atmos. Chem. Phys., 11, 9237–9251, 2011
www.atmos-chem-phys.net/11/9237/2011/
doi:10.5194/acp-11-9237-2011
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Atmospheric Chemistry and Physics

A global climatology of tropospheric and stratospheric ozone derived from Aura OMI and MLS measurements

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Received: 23 May 2011 – Published in Atmos. Chem. Phys. Discuss.: 24 June 2011
Revised: 30 August 2011 – Accepted: 2 September 2011 – Published: 8 September 2011

Abstract. A global climatology of tropospheric and stratospheric column ozone is derived by combining six years of Aura Ozone Monitoring Instrument (OMI) and Microwave Limb Sounder (MLS) ozone measurements for the period October 2004 through December 2010. The OMI/MLS tropospheric ozone climatology exhibits large temporal and spatial variability which includes ozone accumulation zones in the tropical south Atlantic year-round and in the subtropical Mediterranean/Asia region in summer months. High levels of tropospheric ozone in the Northern Hemisphere also persist in mid-latitudes over the eastern part of the North American continent extending across the Atlantic Ocean and the eastern part of the Asian continent extending across the Pacific Ocean. For stratospheric ozone climatology from MLS, largest column abundance is in the Northern Hemisphere in the latitude range 70° N–80° N in February–April and in the Southern Hemisphere around 40° S–50° S during August–October. Largest stratospheric ozone lies in the Northern Hemisphere and extends from the eastern Asian continent eastward across the Pacific Ocean and North America. With the advent of many newly developing 3-D chemistry and transport models it is advantageous to have such a dataset for evaluating the performance of the models in relation to dynamical and photochemical processes controlling the ozone distributions in the troposphere and stratosphere. The OMI/MLS gridded ozone climatology data are made available to the science community via the NASA Goddard Space Flight Center ozone and air quality website http://ozoneaq.gsfc.nasa.gov/.

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1 Introduction

In a previous paper Ziemke et al. (2006) combined ozone measurements from the Ozone Monitoring Instrument (OMI) and Microwave Limb Sounder (MLS) onboard the Aura satellite to obtain global maps of tropospheric column ozone (TCO). The derivation of TCO was based upon a tropospheric ozone residual (TOR) method which involved subtracting MLS stratospheric column ozone (SCO) from OMI total column ozone after adjusting for calibration differences between the two instruments. The TOR concept, which was first applied by Fishman et al. (1990) involved measurements of total and stratospheric column ozone from two separate instruments on two separate satellites. Total column ozone was obtained from the Nimbus 7 TOMS UV backscatter instrument while SCO was obtained from Stratospheric Aerosols and Gas Experiment (SAGE) occultation instrument. Aside from calibration issues involving the use of two different satellite measurements, there was also a serious constraint in producing global data with adequate temporal and spatial coverage. Although TOMS total column ozone was daily with near global coverage, SAGE SCO measurements were limited to ∼30 ozone profiles per day with about one month required to cover the latitude range 50° S–50° N. Chandra et al. (2003) later combined total column ozone from Nimbus 7 and Earth Probe TOMS with Upper Atmosphere Research Satellite (UARS) MLS ozone measurements to derive improved measurements of TCO extending from the tropics to the extra-tropics; that study was the first to use MLS ozone measurements to derive a long record of TCO spanning ∼6 years. Having essentially coincident measurements along each orbital track with current Aura OMI and MLS column ozone is a significant improvement from these previous

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REPORT DOCUMENTATION PAGE

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1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
29-08-2012	Technical Memorandum	

4. TITLE AND SUBTITLE

Atmospheric Research 2011 Technical Highlights

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Atmospheric Research

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Goddard Space Flight Center
Greenbelt, MD 20771

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING/MONITOR'S ACRONYM(S)

11. SPONSORING/MONITORING REPORT NUMBER

NASA/TM–2012-215890

12. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified-Unlimited, Subject Category: 42, 47, 48
Report available from the NASA Center for Aerospace Information, 7115 Standard Drive, Hanover, MD 21076. (443)757-5802

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The 2011 Technical Highlights describes the efforts of all members of Atmospheric Research. Their dedication to advancing Earth Science through conducting research, developing and running models, designing instruments, managing projects, running field campaigns, and numerous other activities, is highlighted in this report.

15. SUBJECT TERMS

Technical Highlights, Atmospheric Research

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19b. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			William Lau
U	U	U	Unclassified	116	19b. TELEPHONE NUMBER *(Include area code)* (301) 614-6332